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THE UNIVERSITY OF ALBERTA

MEMORY AND METAMEMORY OF DEAF STUDENTS

BY

HING FUNG TSUI

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

THE DEGREE OF DOCTOR OF PHILOSOPHY

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DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

EDMONTON, ALBERTA

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Memory and Metamemory of Deaf Students submitted by Hing Fung Tsui in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Special Education.

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DEDICATION

TO MY PARENTS, PAK WAH TSUI AND SHUN YING YEUNG

ABSTRACT

The research study investigated the memory and metamemory abilities of 24 severely to profoundly deaf students with bilateral sensory-neural loss, between the ages of 9 years and 20.42 years. Based on recent cognitive and metacognitive theories, the research purpose was to obtain a descriptive profile of the interactions among different variables.

Metamemory was investigated with four modified subtests from Kreutzer, Leonard and Flavell's (1975) interview, which are story list, study plan, retrieval event and opposites-arbitrary. Encoding was investigated with a spatial position versus temporal position test. Retrieval was investigated with free-recall of a clusterable word list and paired-associate recall of prototypically associated items and non-prototypically associated items. Forward digit span for determining capacity, pre-test word review for knowledge assessment and an interpolated task of color sequence matching were the other measurements used. Testing was conducted in manual communication with a sign language interpreter.

Results indicated that the working memory capacity of deaf subjects was depressed. Inefficiency in encoding was observed. Overall, the results did not suggest a spatial bias in encoding, although different patterns were observed when the sample was broken down into three age groups. It was suggested that the ability to encode both spatial and temporal information is related to some degree of reflective thinking in metamemory. Rehearsal mechanism was associated with temporal position recall and paired-associate

non-prototypic condition. Clustering strategy in free-recall was correlated with knowledge, wheareas performance on prototypic condition in paired-associate learning was highly automatic. Only a slight relationship was found between metamemory and free-recall, and between metamemory and clustering, whereas knowledge was correlated with metamemory and free-recall performance. Age trend was observed in metamemory in general, with different patterns on the subtests. It was suggested that the age trend actually showed the older deaf subjects to be developmentally delayed in terms of expected performance. Also clustering strategy was not efficiently used by all the oldest subjects, indicating a developmental delay. The issue of knowledge structure development seemed to be pertinent to the memory development of the deaf. Future research into executive strategies and procedural metamemory was suggested.

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CHAPTER I

INTRODUCTION

General Background

Memory models were developed and repeatedly modified in the field of psychology, from the earliest associationist models to the more recent models of metamemory (e.g., Flavell & Wellman, 1977; Brown, 1978). Among the many models, there are some which describe information processing in general, and some which are more specific. As far as memory research with the deaf was concerned, conceptualizations from predominant memory models of the time were no doubt in its background.

Issues on Memory of the Deaf

Most memory studies of deaf people have dealt with only a few limited aspects of memory phenomenon which were assumed to be affected by hearing loss or the lack of a verbal language. However, Wolk (1985) has recently criticized such studies as being unable to distinguish between "representational" and "executive" processes.

The representational process or encoding of the deaf has often been related to the deficiency of audition. It was hypothesized that as auditory input is temporal-sequential in nature, the deficiency in the auditory modality would affect sequential information processing (e.g., O'Connor & Hermelin, 1972, 1973).

Another issue of representation has been the use of the imaginal code by the deaf. The use of such a code was inferred from the visual mode of information processing presumably used by the

deaf. The model of dual-coding of Paivio (1971) has also been invoked in studies of the memory of the deaf. However, the studies testing the issues of spatial versus temporal code and imaginal encoding exclusively have looked at the memory performance of the deaf in a passive stance. Other studies which explored the effect of sign formational properties on recall (e.g., Bellugi, Klima & Siple, 1975, Liben, Newell, & Posnansky, 1978) or whether the syntax of sign language produced similar facilitation as verbal languages (e.g.Tweney & Heiman, 1977) have also been limited in scope in that these studies were still concerned with the issue of encoding, and the focus was still on the code used but not the person using the code.

What has been lacking is the investigation of deliberate retrieval strategies which more successful deaf learners use in learning material not congruent with their natually occurring processing mode. This is an important issue related to the memory of the deaf students, because an orthography based on a verbal language is used in schools, and deaf students are often reported to be behind their hearing peers in language skills.

The Research Problem

The recent research on memory development has offered many new implications which could shape the direction of deaf memory research. The present research does not rely on one single paradigm of memory research, using the strategy, metacognition and knowledge interpretations as well as the socio-genesis perspective. According

to new conceptions of memory development, the difference between children's memory and that of adults lies not in the capacity, but in the processes. Qualitative and quantitative differences have been attributed to strategies, metamemory and content knowledge (Chi, 1985).

Strategy development has been postulated as the basic source of cognitive development (Flavell, 1971; Flavell & Wellman, 1977), whereas the metamemory explanation of children's failure to use strategies is their lack of conscious control. In Brown's (1978) view, knowledge of one's cognition or conscious executive control of the routines is the essence of intelligent activity. The focus on a knowledge explanation has been advocated by Chi and Reese (1983) and Trabasso (1983). The representation of the conditions for application of a strategic rule can be regarded as the declarative aspect of knowledge. In this light, the understanding of domain specific knowledge is the first step to understand memory development.

Although the three possible explanations of memory development seem to be separate alternatives, they are facets of the same cognitive and metacognitive umbrella. However, the focus on domain specific knowledge and domain specific strategies seems to be a more profitable direction for research with the deaf. Firstly, the study of general strategies such as rehearsal by means of manual signing or the lack of it was not thought to be conducive to the understanding of strategy change. A more worthwhile issue would be the use of strategy in increasing task complexity within a knowledge

area; in the research context, it would mean looking into the task conditions or levels of task difficulty. Word-understanding has often been taken for granted, but it is a specific domain which is particularly problematic for deaf children, as most deaf school leavers' reading vocabulary seldom progresses beyond that of a 9-year-old (Conrad, 1979), and a plateau of grade three or four reading level is attained by 13- and 14-year-old deaf students (Quigley & Kretschmer, 1982). Although words have been used in memory experiments with the deaf, they have not been employed with a conceptualization that affords them the status of a specific domain under study.

Another adopted view of memory development in the present study is the socio-genesis view of Soviet psychologists. The main exemplifier of this view is Vygotsky (1962, 1978). According to Vygotsky (1978), mental strategies for remembering are reconstructed from social interactions. This is called a shift from the "interpsychological" plane of functioning to the "intrapsychological" plane, and the developmental trend is from involuntary to voluntary memory behavior.

The Soviet view provides a useful perspective for studying a special population as well as underscores the conceptualization and methodology of metamemory investigations. From the stance of socio-genesis, the deaf population can be viewed as a group which has undergone compromised social experience. Rather than from a deficiency perspective, the research perspective is more akin to that of cross-cultural variation. Cross cultural research has shown that

variation of memory performance of non-western groups can be a function of the degree of schooling, mobilization of different cognitive processes, or dependence on different contextual cues for memorization (Rogoff & Mistry, 1985). The deaf could be likewise regarded as a special cultural group which does not totally share the same experiences of hearing individuals.

What the present study attempted to investigate was a spectrum of short-term and long-term memory abilities and metamemory abilities of deaf students. Issues covered pertained to the more familiar question of memory representation, in addition to retrieval. Instead of studying memory representation as the only aspect of research interest, memory representation was examined in relation to other memory abilities. Performance and strategy use were studied in relation to long-term semantic memory, short-term capacity, task conditions, metamemory and age. The concern was whether there was a developmental difference in terms of patterns from what is documented in the literature, taking the deaf sample as a whole, and whether within the age range of the sample, developmental variations occurred. Although the tasks used in the study were not entirely unprecedented, the rationale behind the usage was condensed from the recent development of memory research. As memory skills are essentially learning skills, hopefully the end result and the perspectives adopted in this research will facilitate improvement in the learning strategies of deaf children and adolescents.

Hypotheses

(1) Memory (Recall & Strategy) and Metamemory

Hypothesis 1.1 - There is a significant positive correlation betwen metamemory and recall performance.

Hypothesis 1.2 - There is a significant positive correlation between metamemory and strategy use.

(2) Strategy and Recall

Hypothesis 2.1 - There is a significant positive correlation between appropriate strategy use and recall performance.

(3) Between Memory Tasks

Hypothesis 3.1 - There is a significant positive correlation between word review and performances on paired-associate learning and free-recall.

Hypothesis 3.2 - There is a significant positive correlation between digit-span and temporal-order recall.

(4) Age (Person Variable) and Metamemory

Hypothesis 4.1 - There is a significant positive correlation between age and metamemory.

(5) Age (Person Variable) and Memory (Recall & Strategy)

Hypothesis 5.1 - There is a significant positive correlation between age and recall performance.

Hypothesis 5.2 - There is a significant positive correlation betweeen age and appropriate strategy use.

(6) Task Conditions (Intra-task Variables)

Hypothesis 6.1 - Spatial-to-temporal confusions are significantly less than temporal-to-spatial confusions in encoding.

Hypothesis 6.2 - Performance on the prototypic items of paired-associate learning is significantly superior to that on the non-prototypic items.

Definitions of Terms

Hearing impairment refers to the entire range of auditory impairment including deafness.

Deafness usually refers to a hearing loss of 70 decibels or more averaged across the frequencies of 500, 1000 and 2000 hertz in the better ear (ISO, 1964) that precludes the understanding of speech through the ear alone, with or without the use of a hearing aid (Moores, 1982).

Hard-of-hearing usually refers to a hearing loss of 35 to 69 decibels averaged across the frequencies of 500, 1000 and 2000 hertz in the better ear (ISO, 1964) that makes difficult, but does not preclude, the understanding of speech through the ear alone, with or without a hearing aid (Moores, 1982).

Profound hearing loss refers to a hearing loss of 91 decibels or more averaged across the frequencies of 500, 1000 and 2000 hertz in the better ear based on the 1969 ANSI (equivalent to ISO, 1964) definition.

Severe hearing loss refers to a hearing loss of 71 to 90 decibels averaged across the frequencies of 500, 1000 and 2000 hertz

in the better ear based on the 1969 ANSI (equivalent to ISO, 1964) definition.

Sensory-neural hearing loss refers to the hearing loss which might be due to cochlear or retrocochlear disorder, or due to the composites of the two (Katz, 1978).

Congenital hearing loss refers to the hearing loss which was present at birth, therefore it can include both hereditary and acquired causes (Ginsberg & Thomas, 1978).

American Sign Language (ASL) is the native language of many deaf people in the United States and also in Canada. It is a visual/manual language. ASL is closely related to French Sign Language, because FSL was introduced to the United States in 1817 by Laurent Clerc from France (Wilbur, 1979).

Cherology refers to the formational characteristics of sign language; the term was first used by Stokoe (1960) as a kind of linguistic analysis. It is analogous to the phonological system in oral languages. A "chereme" is a sign unit, analogous to a phoneme. Each sign unit can be described in terms of four parameters: handshape, location, motion and orientation.

Fingerspelling is the use of manual alphabets.

Dactylology is the communication by means of signs made with the fingers, such as manual alphabets.

Signed English is the least well defined system among the various sign systems, although it may be the most widely used one (Wilbur, 1979). Signed English can refer to a sign system developed for educational purposes. Signed English can also refer to a loosely

defined means of using ASL signs in English syntactic order without invented grammatical endings or grammatical signs which allows the use of ASL syntactic devices. Lastly, signed English also refers to the signing of hearing people who put signs together in English order and fingerspell any unknown sign (Wilbur, 1979).

Oral-aural method is a system where input is received through speechreading (lipreading) and amplification of sound, and output is expressed through speech (Moores, 1982).

Total communication is an extension of the simultaneous method which is a combination of oral-aural method, signing and fingerspelling. Another principle of TC is the use of all possible means of communcication based on the individual's needs (Moores, 1982).

Delimitations

Instead of an experimental design, the present study was an descriptive and exploratory attempt to uncover the inter-relationship among the various variables within one single sample of deaf individuals. The approach taken was more akin to diagnosis. Instead of developing a robust experimental design, the aims of the study were restricted to produce qualitative descriptions of relationships in a correlational study.

The size of the sample would be considered small by the standard of experimental design, as there were only 24 subjects. Age groups were not used in the construction of the research method and random sampling was not considered due to various practical problems. One reason was that there is a small population of

profoundly deaf students, since deafness is a low incidence handicap. The approximate prevalence rate for congenital sensory-neural hearing impairment is one per 1000, rising to two per 1000 for congenital plus postnatal childhood impairment (Bamford & Saunders, 1985); the prevalence of profound hearing loss is about 0.5 per 1000 (Upfold & Isepy, 1982). The targeted population was those enrolled in the schools of the deaf, and therefore the number of possible subjects was further reduced. Deaf children enrolled in the public school system were not targeted because homogeneity in regard to hearing loss and exposure to the use of total communication and sign language would be affected. Another reason for the small sample size was that participation was on the condition of parental consent and the personal consent of those students who were in upper secondary level.

Statistics of the number of Canadian deaf students enrolled in elementary-secondary environments were not availabale; what was available was the number of deaf and blind students together, which was 2,675 in 1986-87 (Canadian Government Publishing Center, 1987). Taking an estimation of 50% probability, the number of deaf students in Canada would be around 1,338. The present sample would represent 1.8% of the estimated population, or it would be 0.9% of the total deaf and blind students in Canada.

Summary

In chapter I, the background of the present research was briefly outlined. The implications from recent theoretical developments were adopted in the present research, which were

different facets of the metacognitive view. The stance taken was similar to that of socio-genesis proposed by Soviet researchers. The research purpose was to achieve a better description of the various inter-variable relationships in regard to memory and metamemory of deaf students. The hypotheses and definitions of terms pertaining to deafness were given, and the extent of the research scope was stated.

Overview

What follows in Chapter II is a selected literature review on memory models, issues related to memory development and research on the memory of the deaf. Chapter III consists of the research methodology. Chapter IV is the analyses of results, and Chapter V is the discussion and conclusion.

CHAPTER II

LITERATURE REVIEW

The literature will be reviewed in three sections. The first section will present a brief description and criticism of the various models of memory. Recent cognitive and metacognitive theories of memory development and some related issues will be covered in the second section. The last section will report the studies of memory of the deaf.

Definition of Memory

In psychological research to date, there is no single unitary definition of memory which is satisfactory. Memory is said to be an extremely complex topic, involving many subtopics which is further complicated by the study of memory as a developmental phenomenon (Reese, 1973). According to Meacham (1972), memory is "an epiphenomenon of various cognitive activities" (Meacham, 1972, p.205). Flavell and Wellman (1977) also agreed to the fact that memory is not a homogeneous psychological domain.

The study of memory has always been a matter of model building. The first part of the literature review presents the various models that have evolved so as to give a background to the research studies subsequently reviewed.

Associationist Models

The earliest models of memory are associationist models, which are based on classical stimulus response learning theory.

These models share the concept that one unit of experience in an individual's memory leads to reactivation of other units with which it is associated. However, the various models differ on what the nature of the association is (Estes, 1982). The earliest experiments on memory were carried out by Ebbinghaus (1885), which required the memorization of a list of unrelated words or nonsense syllables. Most of the early investigations on memory are of this nature, and are more commonly known as studies of verbal learning.

The first model based on the assumption of associative connections is the "chain association model", as described by Estes (1982). The validity of this model has been called into question, since the direction of association in free recall experiments could not be predicted according to the model. This model was revised into a model of "multiple association" which allows for simultaneous associations. In order to handle the phenomenon of "categorical clustering" in free recall, other models evolved, such as those of Collins and Quillian (1969) and of Mandler (1967), which adopt the presumption that the memory system is organized in a tree structure of interconnected nodes of semantic information. These are the "hierarchical association models". Anderson and Bower (1973) extended the basic principles of associative theory and drew on psycholinguistic concepts in their more complex "psycholinguistic association" model. The inadequacy of the model, however, is due to the existing gap between the two research frameworks of psychology and psycholinguistics (Estes, 1982).

Another approach, the "associative coding model", is influenced by conceptions of coding in memory. The basic assumption of this model is that when a behavioral event occurs, a trace is laid down in the nervous system. The significance of the trace in the memory functions is that it acts as a "control element" (Estes, 1972) or "interactive filter" (Anderson, 1973) in the network of associations.

The continuous revisions of different associationist models have been due to their inability to explain more complex information processing. Other models have evolved independent of associationist frameworks to achieve better explanatory power.

Structural Models

Models that are based on information processing theory emphasize the flow and direction of information. The structural models focus on information storage, while the process models are concerned with the sequential phases of registration, retention and retrieval. In Watkins' view (1978), both types are versions of the "spatial metaphor", but the storage models which have evolved from the two-store hypothesis are more controversial.

The two-store distinction between short-term and long-term memory has existed ever since memory experiments were reported. Ebbinghaus (1885) noted that errorless seven syllable recitation was possible in a single trial. This phenomenon of "memory span" became the focus of research which showed it to be an index of mental capacity (Galton, 1887; Jacobs, 1887). Memory span, to this day, is

still used in clinical diagnosis. It was William James (1890) who made the distinction between "primary" and "secondary" memory. Primary memory refers to the "psychological present", secondary memory refers to the "psychological past". However, the distinction of memory stores was not widely accepted in the early part of the 20th century, since associationism was dominant. The concept of a distinct short-term memory system was revived later with the work of Broadbent (1958) on audition and Sperling (1960) on vision, which demonstrated the need for sensory registers that could hold unattended information for a brief interval.

Waugh and Norman (1965) adopted the terms primary and secondary memory, which were originally used by James (1890). Waugh and Norman (1965) proposed that the major cause of forgetting for recent events is displacement rather than temporal decay. With rehearsal, the information is either maintained in the primary memory or transferred to the secondary memory. In this two-store model, the two storage systems are functionally related to each other. Atkinson and Shiffrin's (1968) multi-store model is an extension of the two-store model, with more emphasis on the control processes. The model is comprised of three structural features, a sensory register, a short-term store and a long-term store. Two control processes, rehearsal and coding, are reponsible for information retention, transference and retrieval (Atkinson & Shiffrin, 1971). The multi-store model has been subject to criticisms concerning the relationship between rehearsal and retention, direction of the flow of information, memory capacity and forms of coding (Baine, 1986).

Subsequently, Shiffrin (1975) has substantially revised the original multi-store model, and the three memory stores have become more unified. Stimulation from the sensory register could pass directly into the long-term store. Also, the short-term store is regarded as a component of the long-term store, which is currently activated.

Process Models

An alternative approach to structural models is the study of memory processes such as encoding, rehearsal and retrieval. The levels-of-processing model proposed by Craik and Lockhart (1972) represents an attempt to study memory in the process framework. Levels-of-processing refers to the analysis of information through a hierarchy of stages, which begins at the sensory or physical level, through the intermediate levels, to the deepest level, the semantic level. The durability of the memory trace is said to be dependent on the final depth of analysis attained.

One factor that affects processing is the time available for the task, as conceptual or semantic analysis requires relatively more time. Primary memory is viewed as a limited-capacity central processor that reactivates information at one level of processing. Maintenance rehearsal is regarded as a strategy rather than a necessary structural feature (Craik & Watkins, 1973). Several revisions have been produced by Craik and Lockhart and their colleaques after the first introduction of the model in 1972.

Lockhart, Craik and Jacoby (1976) were dissatisfied with the original formulation which suggested that the stimulus is

processed through a fixed series of analysers. The new conception is of "domains" of encoding, with separate processing within each. The characteristics of the stimulus determine the number of domains involved in the processing. The new construct of "encoding elaboration" is introduced in another modification (Craik and Tulving, 1975). Any minimal encoding can be elaborated by further structural, phonemic or semantic encoding. This encoding occurs within the domain, and is known as the "spread" of encoding which involves the context of the stimulus as well.

In the most recent reconceptualization of levels-of-processing, it is suggested that the memory trace is dependent on the distinctiveness and the contrastive nature of the information (Jacoby & Craik, 1979). While elaboration adds more information, distinctiveness emphasizes the contrastive nature of the information when it is in a background sharing other commonalities. Therefore, the distinctiveness of an item is relative to a particular context; this notion is the same as "encoding specificity" (Tulving & Thompson, 1973). If the original context is present at retrieval, there is higher probability to activate more features originally encoded.

Various criticisms of the level-of-processing approach have been voiced. The most common objection is that the approach is based on a circular argument (e.g., Baddley, 1976; Postman, 1975). The inadequacy is that there is no direct measure of the levels, since the level of processing is but a deduction of the amount recalled. Another criticism is the superfluous concept of domain of processing

which does not differ substantially from the postulation of short- and long-term stores. Despite these criticisms, the level-of-processing model has generated a vast amount of research.

Much of the research on semantic memory has used the levels-of-processing approach, especially in developmental research. It has been suggested that the effectiveness of encoding elaboration will depend on the current state of the learner's knowledge (Bransford, Franks, Morris, & Stein, 1979). The levels-of-processing model is also consonant with the view that encoding processes are constructive in nature (e.g., Bartlett, 1932; Bransford & McCarrell, 1974). The semantic level or deep level of analysis is part and parcel of the knowledge base. In more recent research of memory development, it is strongly claimed that what develops is the knowledge base of the children (e.g., Chi & Ceci, 1987). In instruction, Ausubel (1968) demonstrated that effective teaching with the use of "advance organizers" activates what is already known.

With the successive modifications of memory models, the present most adopted approach seems to be the information approach and the levels-of-processing model. Apart from formulations of general memory models, there have also been indigeneous attempts of model building, such as the dual-coding model of Paivio (1971).

Dual-Coding Model

The dual-coding approach of Paivio (1971) has been evolved with influences from Piaget (Piaget & Inhelder, 1966), Bruner (Bruner, 1964; Bruner, Olver, & Greenfield, 1966), Werner and Kaplan

(1963), Neisser (1967), and Berlyne (1965). The main feature of the model is the distinction between two symbolic processing systems: the nonverbal imaginal process and the verbal symbolic process which are independent and also interconnected. These two processes are contrastive as well as relative to each other in three dichotomous dimensions: (a) concreteness versus abstractness, (b) static versus dynamic functions, and (c) parallel versus sequential processing.

(a) The ontogenetic evolution of imagery is associated with increasing capacity for coping with relatively abstract tasks. Paivio (1971) did not suggest that one symbolic mode completely replaces the other, rather the mode of representation generally evolves from concrete to more abstract imagery, overlapping with the emergence of verbal symbolic processes. Images can be relatively abstract and schematic, and abstract ideas can be concretized as specific images.

(b) Paivio's (1971) position is that images are effective in representing static situations as well as changes in situations. Similarly, the verbal system can serve a static representational function as well as transformational functions. Which mode will be functionally dominant is dependent upon the situations, which are affected in turn, by the abstractness-concreteness and parallelness-sequentiality.

(c) The imagery system, according to Paivio (1971) is both "spatially" and "operationally" parallel, and it is specialized in "synchronous organization" of elementary images (Paivio, 1974, 1977). This organization allows for a high degree of integration or

unitization of multi-componential information in memory (Paivio & Desrochers, 1980). The verbal system, on the other hand is "operationally parallel" as well as a sequential processing system. Since the verbal system is related to the auditory sensory modality, it is characterized as having a "sequential organization" (Paivio, 1971, 1977). In sequential organization, the successive steps of processing are interdependent.

With regard to their relations to long-term semantic memory, the two coding systems are involved in three levels of processing. The first level, which is "representational" processing, involves the activation by a stimulus of a corresponding cognitive representation in long-term memory. Thus verbal representations are activated by words, whereas imaginal representations are activated by objects or pictures. The second level is the "referential" level, which refers to the activation of representations in one system by the other through their interconnections. Finally, the "associative" level refers to connections that occur within each system, between linguistic units or between images.

The nature of the representational units has long been a controversial subject. Paivio (1978) subsequently refined his constructs of image and verbal units. The functional units in the imagery system are assumed to be perceptual analogues and contain modality-specific information. These units are the "imagens" as distinguished from other consciously experienced images. The functional units in the verbal system correspond to the existing

units of language and are similar to the "logogens" of Morton (1969), which are semantic and phonemic address features.

Another development of the dual-coding model is the extension to bilingual memory (Paivio & Desrochers, 1980). The general assumption is that the imagery system which represents knowledge of the world and the two verbal systems are all independent but partially connected. The translation equivalents in the two languages may not activate the same imagens, depending on the way the languages have been acquired. In short, the referential meaning is not necessarily identical.

One fundamental dissatisfaction with the dual-coding model is that the imagery system seems to be based exclusively on properties of the visual system. However, imagery can include other sensory modalities as well. Also no attempts have been made to verify the dimensions postulated about the model as a whole. When the model is used in recall experiments, emphasis has often been placed on the stimulus input, i.e., the imagery value, therefore explanation of the retrieval process cannot be extended beyond the initial encoding phase. Kail and Siegel (1977) argued that if long term retention depends on encoding of semantic attributes, the locus of the proposed dual-memory codes remains unclear. It is unclear whether the codes are components of a unitary long-term system or two separate systems.

It seems that the dual-coding model can best be qualified as a hypothesis of mental representation, but its explanatory power for retrieval and executive processes is limited. The next model to

be reviewed, the information integration model of Das and his colleagues (Das, Kirby, & Jarman, 1979), unlike the dual-coding model, is more concerned with processes.

Information Integration Model

The information integration model of Das and his colleagues (Das, Kirby, & Jarman, 1979) is a cognitive interpretation of the work of Luria (1966, 1970). The main proposal of Luria (1966, 1970) concerning brain activities is the "functional interdependence" of various parts of the brain. These neural networks may be described as functional systems.

Three functional systems have been defined. Block one is the reticular formation which is the subcortex and the brainstem. This part maintains the tonal balance of the brain, links environmental stimuli with specific cortical areas via the afferent (ascending) connections, and maintains optimal energy input to the efferent (descending) fibres for regulatory purposes.

Block two consists of the occipital (visual), temporal (auditory) and parietal (general sensory) lobes of the neocortex. The neurons of these lobes are specialized in specific sensory information and are hierarchically organized into three zones. Luria (1966) postulated that the temporal lobe and occipital-parietal region integrate incoming information into successive series, while the occipital and parietal lobes combine stimulus into simultaneous groups.

Block three comprises the cortical areas anterior to the central sulcus and is responsible for the organizational and controlling aspects of conscious behavior. The frontal cortex is divided into three zones, similar to those of block two. Block three is largely an efferent system, with its outlet in the motor cortex. Modality-specific zones are absent, plans are formulated in the tertiary and secondary zones and are passed to the primary zone which transmits impulses to the effectors.

Das et al. (1979) proposed an information integration model which consists of three types of processes corresponding to the three functioning blocks in Luria's (1966, 1970) conceptual framework. The three types of processes are the arousal/attention process, the coding processes, i.e., simultaneous synthesis and successive synthesis, and planning. Four components are hypothesized in the model which are the input, sensory register, central processor and output. Stimuli are received through any sensory receptor and may be presented in either a simultaneous or successive manner. They are then transmitted to the sensory register and passed on to the central processor which comprises the two coding processes and the planning unit. Simultaneously presented input may be processed successively, and vice versa, successively presented input may be processed simultaneously. Task demands, and culturally determined and genetically determined habits influence the choice of processing mode.

Research conducted by Das and his colleagues has demonstrated a relatively stable factor structure derived from tests,

indicating the two coding processes. This pattern of relationships has been maintained across various samples of subjects, who are different in ability, age and ethnicity (e.g., Das et al., 1979; Jarman & Das, 1977; Kirby & Das, 1978; Krywaniuk & Das, 1976).

Ashman (1985) reviewed the more recent studies on the research of coding and planning functions with normal subjects. It seems that there are three stages of development in the interrelationship of coding and planning. For the adults, planning can be subsumed by relatively efficient coding practices. It was suggested that at the adult level, the tests used by Das and his colleagues may not be adequate measures of the aspects of planning, such as goal setting, directed search, hypothesis testing and monitoring behavior. As for adolescents and children, planning and coding have been demonstrated as distinct functions, though it has been argued these functions are interdependent (Ashman & Das, 1979; Das et al., 1979). Planning is apparent in the performance of young children; however, the coding processes are not differentiated. For borderline and educable retarded persons, coding and planning appear to be differentiated. When the level of retardation is more severe, modal specificity of coding is apparent, with a bias towards spatial and visual information; the ability in information integration and organization is also restricted.

In the studies of Das and his colleagues, interpretation is based on factor analsis on similar batteries of tests which are presumed to require the anticipated processes. However, such an approach does not seem to have demonstrated the choice of coding or

the choice of a particular planning routine from the perspective of the subjects. In short, the experiments are conducted in a passive stance, which emphasizes the stimulus variables and ability levels. As the information integration model is a derivative of clinical neuopsychological studies, the logical step of research would be the use of neuropsychological measures. The validity of the processes induced by the test batteries could only be cross-validated through the use of physiological indicators.

The merit of the information integration model is that it is a very parsimonious model, without including concepts extraneous to the main issue of processing, while both the levels-of-processing model and dual-coding model are preoccupied with the content of the level or the code. The next two models to be discussed together, the Piagetian and Soviet developmental models are not so much concerned with memory per se; memory is regarded as just an aspect reflective of cognition in general.

Piagetian and Soviet Developmental Models

In Piagetian epistemology, memory development in the wider sense is inseparable from intelligence (Piaget & Inhelder, 1973). Memory changes are a reflection of the individual's assimilation schemata. The schemata influence not only encoding and decoding of information in the developmental course; the code is susceptible to transformation. As intelligence is a process of construction and reconstructiion, so is memory development. Another feature of the Piagetian view of memory development is that of the role of the

individual, who is seen to be constantly interacting with a potentially meaningful world.

Soviet research has stressed to a greater extent than western research the complex of cognitive activities involved in memory, and the importance of social interactions (Meacham, 1972). The dialectic interaction between the individual and the social-historical milieu is significant for both individual development and the transformation of the structures of society. The sequence of qualitative changes in memory abilites are interpreted as the transfer of control from the external to the internal "mediated act".

Vygotsky (1929) outlined four stages of development of the child, using memory as an illustration. The first stage is characterized by voluntary directed attention. In the second stage, the child might discover some external mnemonic methods, which are of cultural origin, such as counting piles of small beads, although the child does not have the reasoning behind the methods. In the third stage, the child grasps the reason for the use of one mnemonic aid instead of another. Vygotsky (1929) noted that the individual level of development is analogous to the cultural-historical development. The invention of "signs" for task solution is similar to the invention of tools. In the fourth stage, the external activity becomes internalized. The dependence on the self as mediating agent marks the change from the interpsychological plane to intrapsychological plane (Vygotsky, 1962, 1978). Vygotsky's idea is very similar to that of Piaget, whose theory of cognitive development

is that of progressing from sensori-motor to formal operations, and that development of memory is part of this general trend.

> Investigations of memory at this age have shown that toward the end of childhood the interfunctional relations involving memory reverse their direction. For the young child, to think means to recall; but for the adolescent, to recall means to think. Her memory is so "logicalized" that remembering is reduced to establishing and finding logical relations; recognizing consists in discovering that elements which the task indicates has to be found.....
>
> There can be no doubt that to remember an item when thinking in concepts is a completely different task from thinking in complexes, although the processes are compatible with each other. Therefore, the development of children's memory must be studied not only with respect to changes happening within memory itself, but also in relation between memory and other functions. (Vygotsky, 1978, p.51)

Summary

In this section, the associationist models, structural models, process models, dual-coding model, information integration model and developmental models have been reviewed. Apart from the developmental models of Piaget and Vygotsky and the model of Das, all the other memory models which have been formulated are, in different emphases, concerned with hypothetical information-related constructs, such as relationship between units of information (associationist models), information analysis (levels-of-processing), format of information (dual-coding) and the locus of information (two store and multi-store models). Das's model is better described as a model of cognitive processes heavily based on brain functions, in contrast to

information processes. The developmental models are concerned with qualitative changes in cognition and their manifestation in behavior. Both Piagetian and Vygotskian models regard the interaction between the child and the social environment essential for development. Of all models of memory, the levels-of-processing model seems to have been used widely in research studies. However, nearly all the memory models have some unresolved theoretical inadequacies.

Recent Cognitive and Metacognitive Theories

Recent cognitive theories have embarked on the concept of metacognition, which has given a new interpretation to the traditionally investigated topics. Metacognitive studies have been instrumental in giving a framework to cognitive development and learning processes. Flavell (1976) has defined metacognition as the following:

> "Metacognition" refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, e.g., the learning relevant properties of information or data.....Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects on which they bear, usually in the service of some concrete goal or objective.
> (Flavell, 1976, p. 232)

Other new cognitivists such as Chi (1985, 1983), Siegler (1981) and Glaser (1987) have the view that specific domain knowledge is the main factor of developmental and performance differences. Cognitive development in other words, is a process of learning which involves acquisition and structuring of knowledge.

The literature review in this section will present the recent metacognitive and cognitive views in regard to the development of memory. The topics covered pertain to metamemory, strategy development and knowledge development.

Metacognitive Views on Memory

Flavell (1971) and Flavell and Wellman (1977) outlined four broad categories of memory-related phenomena. The first consists of the basic processes, which do not undergo developmental changes. The second category is related to the involuntary effects of general cognitive development, that is, the content and structure of the conceptual system. The third category consists of strategies or voluntary behaviors which serve as mnemonic aids. Lastly, the fourth category is metamemory, which refers to the individual's knowledge of factors affecting memory performance.

Similarly, Brown (1975) discussed different types of memory phenomena and processes which are sensitive to developmental changes. Changes of memorial processes would be of two fundamental kinds. The first is the expansion of the repertoire of specific skills for coping with episodic memory demands. Secondly, maturation would result in modification of the knowledge system, or semantic memory. This distinction is roughly equivalent to Piaget's distinction between memory in the "strict" sense and memory in the "broad" sense. What Brown (1975) described as "knowing how to know" and "knowing about knowing" are respectively memorial strategies and metamemorial knowledge. These come under the development of episodic memory.

"Knowing" which is the knowledge about the world pertains to the development of semantic memory.

Following from their research on memory processes, Campion and Brown (1978) provided another conceptualization on the nature of intelligence. Their theory incoporates Flavell's (Flavell, 1971; Flavell & Wellman, 1977) ideas, Piagetian epistemology, as well as the common ideas of information processing models, such as that of Atkinson and Shriffin (1968). The theory postulates two hierarchical levels: (1) the architectural system, and (2) the executive system.

The features identified in the architectural system are "capacity" in short-term memory, "durability" or the rate at which information is lost, and "efficiency" or the temporal characteristics related to selection and storage of information (i.e., speed of encoding and rate of retrieval search). The architectural system seems to undergo little developmental change after age 5, and decline in the latter part of adulthood. These features are closely related to the sensory register and constitute the perceptual component of the theory. Whereas the architectural system seems to be biologically rooted, the executive system is more environmentally-based and appears to be the product of learning experiences. The four components of the executive system are: knowledge base, control processes (i.e., cognitive strategies), (Piagetian) schemata, and metacognition. Metacognitive abilities involve complex functioning, and knowledge of cognition must be distinguished from the regulation of cognition (Brown, 1978). The self-regulating mechanisms are general strategies or executive

processes which include planning, monitoring and evaluating. All these decision making processes are said to be the hallmark of intelligence (Brown, 1978). Unlike the knowledge aspect of metacognition, these mechanisms are unstable and age independent, in that they are not necessarily used by all adults and older children although they are late in development (Brown, Bransford, Ferrara, & Campion, 1983). Similar ideas have been suggested by Belmont (1978). The distinction between basic operations (control processes) that work on the information to be memorized and superordinate self-programming skills that select, monitor and evaluate the control processes is made. Mature memory performance is characterized by the development of the self-programming skills rather than the control processes.

Metamemory development is divided into two aspects according to Flavell's theory (Flavell & Wellman, 1977). The first is sensitivity to the need for present retrieval or future retrieval. The second is the knowledge of variables (person, task and strategy) and their interaction which affect the quality of retrieval performance. Very young children are often thought to be insensitive to the need for future retrieval. However, research by Wellman, Ritter, & Flavell (1975) and Yussen (1974) showed that young children have differentiation of intentional future retrieval. Yussen (1974) found that 4 to 5 year old children looked at a model more if under instruction to reproduce the model's behavior. In two of Wellman, Ritter, & Flavell's (1975) studies, the children in the "remember" condition exhibited more looking and touching behaviors than the

children in the "waiting" condition, when the goal was to remember the spatial location of toys. Flavell (1977) cautioned against concluding a young child does not understand what deliberate memorization means, since the age at which understanding emerges is partly dependent on task appropriateness. Still, the understanding of 4-5 year old children of mental verbs such as remembering and forgetting is very general and evolves gradually in early childhood (Wellman & Johnson, 1979).

Metamemory Variables

The first type of variables that affect retrieval is "person variables" which refer to firstly, attributes of self or others, such as different ages, abilities etc.. Another type of person variables refers to temporary processes and states, such as the ability to monitor memory abilities (Flavell & Wellman, 1977). Brown (1978) used the term "secondary ignorance" to describe the awareness of one's ignorance, and metacomprehension is the ability to ascertain the state of one's ignorance or enlightenment. Metacomprehension involves complex forms of inferencing and also strategic monitoring of awareness so as to maintain optimal knowledgeability, thus resulting in changes of confidence level and prediction of performance.

Developmental aspects of metamemory have been reported in the monograph by Kreutzer, Leonard, & Flavell (1975). Children from kindergarten, grades 1, 3 and 5 were interviewed. Although some basic concepts of memory ability and memory loss were evident among

the younger subjects, the older children appeared to have a more differentiated concept of the self as a mnemonist. As for here-an-now monitoring, there is evidence that young children are aware of their own level of performance in memory tasks (e.g., Niemark, Slotnick, & Ulrich, 1971; Bisanz, Vesonder, & Voss, 1978; Goodman & Gardiner, 1981). Yet younger children are less able than older ones in assessing their own readiness to recall (e.g., Niemark, Slotnick & Ulrich, 1971); also older children are better in performance prediction than younger children (e.g., Flavell, Friedricks, & Hoyt, 1970; Markman, 1973; Yussen & Levy, 1975; Cultice, Somerville, & Wellman, 1983).

The second type of variables involved in metamemory development is "task variables", which refer to retrieval-relevant properties of the tasks. Retrieval-relevant properties are the relations among the information units and the level of effort requirement. Mature learners are those who are able to distinguish retrieval-relevant properties from irrelevant ones (Flavell & Wellman, 1977). Also different variables may interact and determine the level of difficulty of a task (Kail, 1984).

Some developmental evidence exists concerning knowledge of characteristics of information such as familiarity, quantity and organization. Familiarity was believed to be an important determinant of memorability of items by 6- and 7-year-olds in Kreutzer et al.'s (1975) study and by the 7-year-olds in Moynahan's (1973) study. Quantity was also recognized as an important factor affecting memory by most of the younger children in Kreutzer et al.'s

(1975) study, and by the 3- and 4-year-olds in the studies of Wellman (1977) and Yussen and Bird (1979). However, children do not seem to take into consideration the relationship among items which attenuate the impact of quantity. This point is illustrated by a finding in Kreutzer et al.'s (1975) interview. Children were shown two lists with associate pairs. One list consisted of names and actions (e.g., Mary, walk), the other one consisted of highly associated antonyms (e.g., laugh, cry). Unlike the 9- and 11-year-olds, the 6- and 7-year-olds could not see the reason for the difference of memorability. Also the 6- and 7-year-olds attached more importance to the quantity of information rather than the association between the pairs. The 10-year-old children in the study of Moynahan (1973) were more likely than the 7-year-olds to predict that categorized items are easier to remember. Similarly, 6-year-olds in Salatas and Flavell's (1976) study were found to be unaware of the mnemonic advantage of categorized organization. However, the young children in Moynahan's (1973) study understood that nonrandomized linear sequence is easier than randomized items. The issue of memory organization will be dealt with in more detail in a later section of the review.

Children's understanding of variable interaction was investigated in several studies. Wellman (1978) asked children to judge the difficulty level of problems in which one variable was relevant and also problems in which two variables were involved. The variables were effort and quantity of items. Both 5-and 10-year-olds answered one-variable problems accurately. However, the 5-year-olds'

performance on the two-variable problems was far worse than that of the older children. Furthermore, the 5-year-olds judged the difficulty of problems on one dimension. In a subsequent study (Wellman, Collins, & Glieberman, 1981), 5-, 8-, 10-, and 19-year-old subjects were asked to predict the number of items a hypothesized person could recall. All the subjects took both variables into consideration. However, the young children's predictions were more influenced by effort. It seems the ability to evaluate two variables equally appears very late in development as shown by the 19-year-olds in the study.

The last category of variables is "strategy variables". Flavell (1977) defined strategies as potentially conscious activities carried out voluntarily as means to various mnemonic ends. Pressley, Forrest-Pressley, Elliot-Faust, and Miller's (1985) definintion of strategy is that it is composed of cognitive operations for achieving a cognitive purpose and is potentially conscious and controllable. A strategy is described as a procedure, which is a rule or a set of rules that can be applied in a variety of situations and perhaps across several domains (Chi, 1985). Rigney (1978) defined cognitive strategies as general procedures that facilitate acquisition, retention, and retrieval across different categories of subject matter. Cognitive strategies were said to involve representational capabilities (e.g., reading, imagery, speech, writing and drawing), selectional capabilities (attention and intention) and self-directional capabilities (self-programming and self-monitoring).

The metamemorial knowledge of strategies would mean that the individual knows which strategy to use in varying conditions and also the procedures involved in the application. Also, this would require the use of executive processes or general strategies as suggested by Brown (1978) and Flavell (1976), such as monitoring, planning etc..

In a recent paper, Pressley, Borkowski, & O'Sullivan (1985) proposed a more articulated model of metamemory about strategies (MAS). The distinction between "declarative" and "procedural" knowledge introduced by Chi (1984) was used as the basic assumption. Procedural knowledge is the know-how, i.e., strategies, and declarative knowledge is the factual knowledge about strategies. Altogether six components of procedural and declarative knowledge make up MAS.

(1) A sophisticated learner is assumed to know a number of strategies such as cumulative rehearsal, meaningful organization, hierarchical effort allocation, imagery elaboration, verbal elaboration etc.. This component is Learner's Strategies.

(2) General Strategy Knowledge includes the knowledge that strategies require effort and proper application.

(3) Specific Strategy Knowledge is unique information associated with a strategy, such as when, where, why a strategy was acquired, and occasions it was used successfully.

(4) Relational Memory Strategy Procedures are metarules which distinguish and classifiy similarities among strategies.

(5) Relational Memory Strategy Knowledge is a product of the previous category. It is concerned with procedures which reorder the representations of strategies.

(6) Metamemory Acquisition Procedures are metarules for acquiring specific strategic knowledge. MAPs are evaluative procedures, such as self-testing and comparing.

Strategy Use and Development

In terms of developmental differences in the use of strategies, Flavell (1970, 1977) distinguished between "production deficiency", "mediation deficiency" and "production inefficiency". Production deficiency refers to the failure to produce a strategy spontaneously for reasons not due to the lack of ability to enact it, while mediational deficiency refers to the execution of the strategy which is not facilitative to the task performance. Production inefficiency refers to the strategy not being carried out efficiently because the underlying skills have not been well developed. The strategy use of very young children and poor performers has been characterized as showing production deficiency, production inefficiency or mediation deficiency.

The use of strategies has been an important topic in developmental research. One strategy that has been frequently investigated is rehearsal. Rehearsal is not a single strategy; it can refer to a class of mnemonics, from simple naming of stimuli covertly or overtly to generating an association for the stimulus and

repeating them together (Kail, 1984). Therefore, the two questions of interest are the age at which rehearsal emerges and the pattern of development. The adolescent years seem to be the turning point for increased sophistication of strategy use, towards a trend of using constructive strategies, such as elaboration and inference (e.g., Paris, 1975; Paris & Lindauer, 1977).

Since organization and elaboration are being investigated in the present research, they will be discussed in greater detail. Organization will also be reviewed again in the light of knowledge structure, since the way information is structured bears close relationship with strategy selection.

Organization as Strategy

Organization can be regarded as a very general strategy of unitization. Several other elementary processes such as search, comparison and rehearsal may be involved (Pelligrino & Ingram, 1979). The earliest associationist approach to the study of memory organization with serial learning and paired-associate learning was based on the laws of frequency and contiguity. Current approaches are in terms of acquisiton of relations and the definition of relations between event units (Voss, 1979; G. Mandler, 1979). Memory organization is not only a retrieval phenomenon, nor determined by the properties of the stimuli themselves. Instead, memory organization is an interaction between the learner and the stimuli. The optimal organization of items that can maximize recall is determined by the individual's experience (Postman, 1972). Since

organization is also imposed by the individual, the presence of taxonomic, semantic or conceptual categories must be discovered and then utilized in recall (Mandler, 1967).

In Moely's (1977) classification, two types of memory organization are identified. Primary organization refers to certain consistent ordering of recall which does not depend on an individual's knowledge of relations between the items, while secondary organization is based on perceptual and semantic relations between items. Primary organization is also referred to as "organization in the weak sense" by Postman (1972). Recency, seriation, primacy and priority can be regarded as strategies of primary organization. Semantic clustering is a strategy of secondary organization.

Recency typically refers to the enhanced recall of items at the end of a list, it may also refer to the strategy of recalling the terminal items first. The early appearance of recency strategy seems to be automatic and is explained as resulting from efforts to maintain the items in awareness during the interval between presentation and recall (Craik & Lockhart, 1972). It is also regarded as a learned strategy developed as a result of multi-trial free-recall (Maskarinec & Brown, 1974). Seriation is an ordering strategy that may result from attempts to rehearse serially. Primacy strategy is increased recall of items that are presented initially. Priority is a strategy whereby items not previously recalled are given special attention in recall. Postman (1972) pointed out that both seriation and semantic clustering give rise to superior

performance in list learning, although the two bases of organization are incompatible. Mandler (1969) argued that seriation is pervasively used in free-recall, and sometimes it is the preferred mode of organization.

The study of organization of children's free-recall is based predominantly on measures of output, that is, clustering and subjective organization in recall protocols. The measures of seriation and recency in output are often documented in literature regarding rehearsal, although these two are also measures of primary organization. Dissatisfaction with output measures has engendered studies of input organization, that is, organization during encoding time. More recent developmental literature has the emphasis on the relationship between organization and knowledge or semantic memory.

The use of recency strategy seems to appear very early in development. Goldberg, Permutter, and Myers (1974) reported that 2-year-olds recalled the second item first when given pairs of items for recall. Serial position curves indicated superior recall of recently presented items for all age groups. The difference between older and younger subjects was the size of the set of recently presented items; 5- and 6-year-olds showed superior recall for the last two items (Thurm & Glanzer, 1971), while eighth graders and college students showed excellent recall for the last three to five items presented (Cole, Frankel, & Sharp, 1971; Hasher & Clifton, 1974).

Seriation strategy is not reported to be common among children below 4 years of age, and it is inconsistently used by

4-year-olds and frequently used by 5-year-olds (e.g., Rossi & Rossi, 1965; Rossi & Wittrock, 1967, 1971). At later developmental levels, there is a shift from organization based on serial ordering to semantic relationships. The age shift is reported to be between the ages of 5 and 11 years (Moely, 1968; Kobasigawa & Middleton, 1972).

Primacy rehearsal is associated with giving priority to recall items presented in the initial positions. Six-year-olds are more likely that 5-year-olds to engage in rehearsal and produce superior recall of items from initial positions (Thurm & Glanzer, 1971). The strategy of giving priority to items not previously recalled does not appear among preschool children (Newman & Edmonston, 1973; Rosner, 1974). Newman (1975) has demonstrated that the adoption of this strategy appears about 8 years of age. The age at which rehearsal is used has been found to be at approximately 7 years old (e.g., Flavell, Beach, & Chinsky, 1966; Cuvo, 1975; Ornstein, Naus, & Liberty, 1975). Age difference is evidenced in the manner of rehearsal (e.g., Cuvo, 1975; Ornstein, Naus, & Liberty, 1975; Ornstein, Naus, & Stone, 1977). Young children's rehearsal is limited to repetition of single items. Older children and adults are found to be more proficient, with several items rehearsed together. Another developmental difference is the growing flexibility. In the study of Ornstein, Naus, and Liberty (1975), 20 words of familiar categories were presented randomly. Only the 13-year-olds rehearsed the members of a category consistently; 10-year-olds did so occasionally, but the 8-year-olds did not.

In general, clustering strategy is found to increase with age. Older children and adults are likely to cluster into categories in free-recall of items from several taxonomic categories. One unresolved question is when the tendencies of clustering appear, and there is little agreement among investigators on this matter. Some researchers found that substantial clustering is a late development, at the end of elementary school years (e.g., Furth & Milgram, 1973; Lange, 1973), while other researchers found that children below the age of 5 showed clustering (e.g., Rossi & Rossi, 1965; Myers & Permutter, 1978; Rossi & Wittrock, 1971).

Semantic relations between items were first proposed by Lange (1973, 1978) as important in determining clustering. Therefore different items used in different studies produce controversial results. The effect of knowledge base on organization has become more central in later investigations using sorting procedures at input time.

Developmental differences in sorting are generally found; however, under certain conditions, even young children use active organizational strategies. A lower degree of semantic organization was found in fourth graders as compared to adults. When the fourth graders learned the sorting patterns of adults, better recall was obtained (Liberty & Ornstein, 1973). In another subsequent study, Bjorklund, Ornstein, and Haig (1977) examined the relationship between recall and input organization of three grade levels. Most seventh graders sorted semantically, while fifth graders' style was variable, and the third graders' style was random. Yet instructions

on adult-patterns given to third graders were sufficient to enhance their recall. These results suggest that young children have knowledge of semantic relations, but they do not apply it strategically. When children are given specific instructions to group things according to meaning and allowed to reach a stable sorting criterion, they sort in a similar fashion as adults (e.g., Worden, 1975; Lange & Griffith, 1977).

One explanation for young children's failure to use organization strategies in recall of taxonomically related list is that the stimuli do not correspond to their semantic memory (e.g., Worden, 1976; Denney & Ziobrowski, 1972). There is evidence that young children's conceptual knowledge is schematically organized (e.g., Mandler, 1983; Nelson, Fivus, Hudson, & Lucariello, 1983) and that schematic organization is used by them to aid recall (e.g., Kirastic, Siegel, & Allen, 1980; Saarnio & Bjorklund, 1984).

Another explanation is stimulus saliency. Stimulus conditions which are salient enable young children to use active organization strategies. Bjorklund and Zeman (1982) demonstrated the effect of stimulus familiarity in one study. Performance of first, third and fifth graders in taxonomic items was contrasted with that using names of classmates. Developmental trends were observed in the recall and clustering of taxonomic materials, whereas minimal differences across age were found in the recall of names.

Naus and Ornstein (1983) suggested that in some situations, pre-experimental knowledge base is reflected rather than deliberate use of strategies, whereas in some other situations, memory strategy

usage is affected by the knowledge base. It seems the influence of the knowledge base will vary, depending on the memory processes required of the task.

A strategy such as labeling would be less dependent on knowledge base effects along the continuum of memory-related activities, whereas verbal rehearsal or using organization is highly involved with the person's knowledge of the material. As for highly automatic processes, external indication of knowledge-base effects may not be discerned. The reason underlying the variation across tasks is that knowledge-base effects can be direct or indirect (i.e., strategy-mediated). Knowledge base can also affect memory performance by influencing the development of memory strategies (Naus & Ornstein, 1983). The relationship between knowledge base and memory as demonstrated by different research approaches will be discussed in another section.

Organization as Representation

In the preceding section, organization was looked upon as a process involving strategies; organization can also be studied as different types of mental or knowledge representations. The terms organization and structure are often used interchangeably, both denote relationship among a set of mental representations. G. Mandler (1979) suggested that three types of organization or structure are studied in memory research. These are the coordinate, subordinate and proordinate structures.

Coordinate structures are relational, involving two or more units. The structure is described as holistic, as access to one part entails access to the whole set of structure. Subordinate or categorical structures are usually hierarchically organized. The relationship is between the superordinate concept and the subordinate units. Proordinate or serial structures are organized in a ballistic sense. Access to a target unit depends on the access to the preceding units. All three kinds of structures are constrained by the capacity of memory span. Longer proordinate structures are probably constructed out of more subordinate structures. More complex structures can be formed by combining different principles of organization.

With regard to the utility of these structures in memory, G. Mandler (1979) suggested that coordination is an important strategy for paired-associate learning, proordination for serial learning, and subordination for free-recall. However, the performance of the three memory tasks often calls upon more than one structure for effective organization.

Another system of defining organization is in terms of the meaningfulness of the events and objects. This is a qualitative approach couched in terms of semantics and pragmatics (J. Mandler, 1979). Two broad kinds of organization were suggested by J. Mandler (1979); these are the categorical and schematic organizations, which are not mutually exclusive to each other.

Categorical or taxonomic organization as described in this system is slightly different from the one offered by G. Mandler

(1979). Although the principal connection is vertical, the hierarchical structures involve superordinate, subordinate as well as coordinate classes. Categorical organization is said to be flexible, in the sense that objects can be classifed in different ways by varying the principles of similarities and differences. Flexibility is one basis of our problem solving abilities, but this aspect makes retrieval ambiguous. Also, temporal or spatial order does not play a part in categorical organization.

In contrast, schematic organization is a spatially and/or temporally organized structure in which the parts have been experienced as contiguities in space or time. The schema is the basis of expectations. The parts of the schema can be likened to slots which can be instantiated by values in terms of probability of occurrence. The more generality exists in the schema, the less predictable are values that may fill the slots. A schema is different from a concept which pertains to class membership. It is rather a limited set of expectations that have functional significance.

Other descriptions have been given in regard to the nature of schema. Schema is said to be a kind of bottom-up processing. However, once a schema is activated by incoming information, it can cause top-down processing; also, it can be hierarchically organized (Chi & Rees, 1983). Schemas have been variously named as "scripts" (Schank & Abelson, 1977) and "frames" (Minsky, 1975). It is claimed by Nelson et al. (1983) that scripts are a basic form of knowledge

representation for young children. Scripts are said to be the "memory in the broad sense" or general knowledge, yet they appear to be a form of episodic memory as well since they are derivations from specific experiences in the real world (Nelson et al., 1983).

Networks and production rules are two other kinds of mental structures. A set of networks or a group of production rules can be regarded as a schema (Chi & Rees, 1983). Networks are associative relationships between concepts and are usually representations of factual or declarative knowledge (e.g., Anderson, 1976; Collins & Quillian, 1969). Production rules, on the other hand, as used by Newell and Simon (1972) are generalized rules based on conditions of occurrence, and are ideal for representing procedural knowledge (Chi & Rees, 1983).

This part of the review on organization has shown that information or knowledge can be perceived in terms of its internal structure, and in terms of how it is perceived according to meaningful or functional relationships. Thus, the scene is set for a more thorough discussion of the role of knowledge base in memory.

Knowledge Base and Memory

Some research directs attention to the role of knowledge or semantic memory in retrieval performance, due to the inadequacy of using strategy-deficiencies as the sole explanation for developmental differences. Age differences are still found in research approaches which have minimized the necessity for strategy use or its differential use. For example, Huttenlocher and Burke (1976)

explicitly provided children of different ages with a grouping strategy in a digit-span task. Although both older and younger children benefited from the grouping, the age difference remained. Thus, the other possible explanation seems to be knowledge difference.

Studies on constructive memory also implicate developmental differences as a result of knowledge difference. Constructive memory research is based on the claim that during encoding and/or recall, general knowledge base influences the construction or reconstructiion of the input information. This assumption is supported by research with adults (e.g., Bransford & Franks, 1971) and with children (e.g., Landis, 1982). The influence of knowledge base was demonstrated even in the same age group in the study of Gobbo and Chi (1986) who assessed two groups of 7-year-olds on the knowledge of dinosaurs. The children were made up of experts and novices in terms of their knowledge in the domain. The expert children gave implicit in addition to the explicit features, and were able to make inferences about the unfamiliar pictures, whereas the novices could only describe the explicitly presented features.

The important part played by knowledge has also been suggested by research of memory in practical contexts. Istomina (1975) showed that 3-year-olds could remember twice as many items from a shopping list while playing "store" than in a formal laboratory setting. According to Chi and Ceci (1987), the familiar game setting activated a prestored script of shopping. In cross-cultural research, Scribner (1977) arrrived at a similar view

that concrete experiences facilitate the inferences of nonliterate children and adults. Similar results have been obtained on social class differences within a given culture. It has been shown that children with lower socioeconomic background sort items on the basis of thematic relations, whereas middle-class children use abstract categorical groupings (e.g., Siegel & McBane, 1967; Siegel & Olmstead, 1970). However, recent research showed that social class differences in categorical grouping can be removed if the stimulus materials are culturally salient to the children (Simmons, 1985).

Chi (1978) suggested differences in encoding and identification times are due to the amount and structure of knowledge in semantic memory which influence access to the information. The study of retrieval variability by Ackerman (1982, 1983) supported this argument. Seven-year-olds, 9-year-olds, and college students were presented words with input cues. At retrieval time, either congruous or incongruous retrieval questions were given. The young children were more penalized when the incongruous questions were given.

In order to elucidate the role of knowledge, some research studies control the degree of semantic knowledge. Richman, Nida and Pitman (1976) and Ceci (1980) attempted to achieve the control by equating the meaningfulness values of stimulus words. Richman et al. (1976) showed that for the same words, older children learned more rapidly than younger children. However, when different words were used for each group, with meaningfulness values held constant across grades, learning differences were minimized. Meaningfulness of a

word is the richness of the semantic interconnections surrounding the word concept. In a free recall task, Ceci (1980) first gave extensive semantic training to 4-year-olds. The subsequent recall of the long list of animals increased as a linear function of the number of interconnections among the animals. While the older children in the study possessed sufficient knowledge to form interconnections, the younger children required experimenter-provided knowledge.

The influence of knowledge has also been demonstrated in studies which manipulated specific domains. For example, Chi (1978) studied the performance of adults and 10-year-olds on memory span and chess positions. The 10-year-olds were slightly more knowledgeable than adults on chess knowledge. A cross-over effect was obtained in which the 10-year-olds outperformed the adults on memory of chess positions, but at the same time recalled fewer digits than adults. A crossover effect in recall was also found by Lindberg (1980), using words norms for adults and words of children's cartoons and games and by Barrett (1978), using nouns generated by young adults versus those of older adults.

Knowledge Structure Development

What the preceding section has dealt with is knowledge interpretations for memory research. The review here will focus on the knowledge structures or representations of children, or their long-term semantic memory.

According to Chi and Ceci (1987), the most plausible assumption about development of knowledge representation is the

reorganization of existing knowledge hierarchies, so that more salient, abstract, or important attributes are stored at the higher levels of hierarchies. Both children and adults could have hierarchical representation of concepts, but the difference is in the content of the modes. The separate modules of knowledge that a child acquires could be locally coherent. Development is attained when new linkages among the localized modules enable the child to understand the structure in another way.

The structure of conceptual knowledge has been uncovered by techniques such as multi-dimensional scaling and clustering analysis (which has been discussed earlier). Two general developmental findings are provided through the multidimensional scaling method. The first is that the dimensions of older children tend to be more abstract; the second is that young children lack some of the dimensions of the older children (e.g., Howard & Howard, 1977; Bisanz, LaPorte, Vesonder, & Voss, 1978). The general findings from clustering analysis are that the degree of association between concepts tends to be weaker and more idiosyncratic in younger children, and the nature of association is more perceptual. Recent research gives a more positive view on young children's competence to form taxonomic classification (e.g., Goldberg, Permutter & Myers, 1974). However, "true" superordination is not achieved until early adolescence, according to Winer (1980).

Lange (1973, 1978) first suggested that young children are more likely to use associative relations than categorical relations. The available literature indicates that children's early semantic

concepts are based on functional/thematic/complementary rather than similarity/taxonomic relationships (Bjorklund, 1985). Children's conceptual organization is said to be script-like (Nelson et al., 1983) and schematic (Mandler, 1983). Both scripts and schemas reflect functional relationships. Denny (1974) suggested the shift from using complementary relations to similarity criteria occurs between the ages of 6 and 9. Younger children seem not to lack the ability of using taxonomic classification, and can use the skill after training, although the effect may not persist. This was the case with the 5-year-olds in the training study of Smiley and Brown (1979).

The ideas of Rosch (1973, 1978) provided a framework to consider the differences of children's knowledge structure. As formulated in the principles of categorization of Rosch (1978), a category which is at the basic level possesses perceptual, functional attributes common to all or most members of the category. Categories that are one level more abstract are superordinate categories in which few attributes are shared among the members. Categories below the basic level are subordinate categories containing common attributes and also attributes that overlap with other categories. For example, "chair" is a basic level category, "furniture" is a superordinate category, and "kitchen-chair" is a subordinate category. Both superordinate and subordinate categories have lower cue-validity than the base-level category. Base level categorization is in line with the principle of cognitive economy which provides most information with the least effort (Rosch, 1978).

It has been suggested that young children are capable of taxonomic categorization, but they are more proficient with base-level objects (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976; Mervis, 1980; Mervis & Crisafi, 1982). This phenomenon is explained by the concept of prototypicality (Rosch, 1978) or best example theory (Mervis, 1980). In the study of Rosch et al. (1976) preschoolers were asked to name a variety of pictures which could be labelled at either the subordinate, basic or superordinate level. The labels given by the children were all at the basic level, although the children at the post-test questioning indicated their knowledge of the appropriate superordinate labels as well. Dougherty (1978) investigated the ethnobotanical nomenclature of American children and found that plants were first named at the basic level. Also, it has been shown that parents used basic level names for their children (Anglin, 1977). These findings all pointed to the special and fundamental role in category development played by base-level exemplars.

Rosch (1973) suggested that children first learned the prototypes and then the less typical exemplars. Pre-school children tend to deny categorical membership to atypical exemplars (Anglin, 1977; White, 1982), and Saltz, Soller, Sigel (1972) only found developmental differences between younger and older children when atypical exemplars were used in a classification task. In a recent study of Bjorklund and Thompson (1983), children's category selection and also judgments of typicality were obtained. The same test words were also given to college students for rating of typicality.

Significant correlations were found among the ratings across groups, also the ratings of the sixth grade group were more correlated with the adults' ratings than those of the third grade and kindergarten. Although children's word concepts seem to affirm the protoypicality hypothesis, the nature of the prototypes are not necessarily identical to adults'. These differences in the content and structure of semantic categories are minimized when the child reaches 9 or 10 years of age (e.g., Bjorklund & Thompson, 1983; Duncan & Kellas, 1978, Keller, 1982).

In general, the knowledge structures of young children have been found to exhibit some similarities to that of older children and adults, but the particular aspects differ, such as their structures are more dependent on perceptual features and prototypes, and classifications are more determined by base-level objects or functional associations. Hence, there is reason to believe that children's use of strategies in deliberate memory task situations are in fact reflective of the existing state of knowledge structures.

Elaboration Strategies

Elaboration is a strategy heavily dependent on the existing semantic knowledge that a person possesses and how the knowledge is used in interaction with the task information. Elaboration strategy is said to require a symbolic construction, which makes the new information more meaningful after combination (Rohwer, 1970).

Elaboration strategies share a common conceptual base of the classical mnemonic systems which assume that perception,

imagination, and thought are continuous modes of experience (Weinstein, 1978). The mnemonic system of the Greek poet Simondes (ca. 500 B.C.) utilized vivid imagery and spatial organization (Yates, 1966). In fact, the mediation of symbolic and perceptual modalities has been the theme of memory theory (e.g., Paivio, 1971). Elaboration strategies can cover a whole range of mnemonics which involve organization, encoding and recoding, and code transformation. For example, the method of loci and story mnemonic are both organizational menemonic devices based on the criteria of constructability, discriminability and associability. The former creates an extrinsic cognitive cueing structure, while the latter utilizes an intrinsic cueing structure (Bellaza, 1981). Concrete words can be encoded as visual imagery based on associability and invertability, while with the same two criteria, abstract words can be recoded into a semantically or phonetically associated word (Bellaza, 1981). Very often, verbal and imaginal elaborations overlap with each other in one strategy.

The elaborative conception of event representation has been formulated by Rohwer (1973, 1980) who suggested that the basic units of memory are events which are unitized according to shared regularities of relationships. Age differences observed in the effectiveness of indirect prompts for constructing associative information suggest that prior relevant events have to be experienced through direct interaction before they can be reenacted. This view is consonant with the view of memory as organized into schemas or

scripts, the Soviet dialectical view and the influence of knowledge as discussed previously.

Developmental differences have been found in the use of various elaboration strategies. Instructions to construct verbal elaborations are effective with preschoolers. Children as young as 3 years old can construct a relationship involving a verb or preposition, when given two nouns (e.g., Bloom & Lahey, 1978). The ability to generate mental images under instruction appears first with concrete materials, around age 5 to 6 (e.g., Danner & Taylor, 1973; Yuille & Catchpole, 1973; Levin & Pressley, 1978). By age 7 to 8, children can utilize the strategy with verbal materials (Begg & Anderson, 1976, Kemler & Jusczyk, 1975). Imaginal manipulation skills increase between the ages of 5 and 13 years, corresponding to the development of spatial manipulation skills (Dean, 1976).

The spontaneous use of elaboration is an important developmental difference. The propensity to elaborate under indirect conditions increases as a function of age, and there is variability in this propensity even within age groups (Rohwer, Raines, Eoff, & Wagner, 1977).

Rohwer et al. (1977) asked groups of 11- and 17-year-olds to learn a list of paired-associates under control instructions. On the basis of this pre-test, the 11- and 17-year-olds were classified as good, medium or poor associative learners. The subjects were presented with another paired-associate list to learn, and were divided into verbal-generated condition, repetition-control condition and control condition. Among the 11-year-olds of all three ability

levels, performance in the verbal-generated condition was superior to that of the other conditions. Among the medium and low ability 17-year-olds, the verbal-generated condition was likewise superior to the other conditions. However, the high ability control 17-year-olds performed at the same level as the verbal-generated subjects. Both these groups outperformed the high-ability repetition-control subjects. From these results, it was inferred that the high-ability 17-year-olds used spontaneous elaboration, while the medium- and low-ability adolescents and 11-year-olds did not.

In the interview study of Pressley and Levin (1977) on the strategies of fifth graders, seventh graders and ninth graders, the use of elaboration was associated with increasing age. At all age levels, higher learning performance was observed among elaboration users in paired-associate learning. The majority of grade 5 children (53%) reported exclusive use of repetition; only 6% of grade 5 children, 15% of grade 7 and 22% of grade 9 children used exclusive elaboration. However, efficient elaboration strategy was exhibited by a minority of the older students. Also task complexities reduced the effectiveness of spontaneous elaboration of young adolescents (O'Sullivan & Pressley, 1982; Levin, Dretzke, McCormick, & McGivern, 1982).

Nevertheless, elaboration strategies are trainable; children as young as 4 years of age (e.g., Borkowski, Levers, & Gruenenfelder, 1976) were able to maintain simple elaborations. In addition, 6-year-old children could maintain interogative strategy (Kestner & Borkowski, 1979). The evidence on transfer, however,

indicates that elementary school children do not always generalize elaborative strategies. In Pressley and Dennis-Rounds (1980) study, 10- to 11-year-old children and 16- to 17-year-old adosescents were given two associative tasks and then a transfer task of Latin definitions. Subjects were either instructed the keyword method to learn the associative tasks or were given a no-strategy control condition. Then, subjects who were instructed the keyword method were presented with the Latin words either with or without a prompt for strategy usage. At the younger age level, the learning of latin words of the children previously given keyword instruction did not differ from the no-strategy control children. However, the 10-to-11-year-olds who were prompted to use a similar strategy for the Latin words, learned more words than control subjects. At the older age level, prompting was not necessary to produce higher Latin learning after the keyword instruction. These data suggested that adolescents are more likely to generalize elaboration than younger children, and that the need for indirect prompt decreases with increasing age during adolescence.

Various theories have been advanced to explain the development of spontaneous elaboration. One theory is that elaboration skills develop with increasing age because of increasing knowledge of event relationship (Rohwer, 1980). Greer (1979) has shown that spontaneous associative strategies are related to formal operational thinking. A third alternative explanation is that of metamemory. Beuhring (1981) has recently demonstrated a relationship between the use of elaboration and general knowledge about memory

variables, and between elaboration and specific knowledge about elaboration.

In the next section, the relationship between metamemory and memory behavior will be pursued further. The studies selected in the review are mainly concerned with strategy usage.

Metamemory-Memory Relationship

Most of the empirical studies concerned with the development of metamemory have relied on the broad conceptualization suggested by Flavell and his colleagues (Flavell, 1971; Kreutzer et al., 1975; Flavell & Wellman, 1977). However, the vagueness of the concept (Cavanaugh & Permutter, 1982; Wellman, 1983) has posed problems in determing the method for assessing metamemory. Because the concept of metamemory covers several categories of variables, and the relationship between metamemory and memory performance is investigated in a variety of experimental procedures, discrepancies among research conclusions have resulted (Schneider, 1985).

The connection between metamemory and memory performance is speculated upon because recent research interest is more concerned about prediction of memory behavior. Flavell and Wellman (1977) did not expect the finding of a strong relationship between metamemory and memory empirically, without taking into consideration other conditions such as age, task demands and motivational factors. Studies that assessed the metamemory-memory connection in sort-recall tasks revealed only a weak to moderate relationship (Cavanaugh & Permutter, 1982), whereas studies on memory monitoring showed a more

positive relationship between metamemory and memory (Wellman, 1983). Schneider (1985) carried out a meta-analysis of a large number of research findings, and the correlation derived between metamemory and memory was moderately high. The relationship between metamemory and memory was moderate in monitoring studies of young children. The association was stronger in training studies of organization strategies with younger age groups. A positive pattern of results was found in studies of organizational strategies, training studies of organizational strategies and monitoring studies (Schneider, 1985).

The review here will be based largely on Schneider's (1985) work, and will concentrate on the literature regarding metamemory and organizational strategies, since this is directly relevant to the present research study. In studies of memory organization, the related metamemory would be the verbalizable knowledge of the role of organization in recall. The memory behavior assessed would be the input organization, output organization and the amount of recall. Some studies also manipulated the source of organization failures by incorporating instruction or task conditions (Schneider, 1985).

Salatas and Flavell (1976) gave a sort-recall task to first-grade children. The children in the experimental condition were given instruction to remember a set of clusterable pictures, whereas the children in the control condition were asked to look at the items. As expected, recall was significantly higher for the experimental condition. The experimental group also gave more correct answers in a subsequent metamemory test. However, metamemory

was not related to sorting behavior during the study trials and it could not predict the strategic behavior in a retest. Subjects who had not categorized during study trials were as likely as categorizers to indicate the facility of grouping in the metamemory test.

The study of Wimmer and Tornquist (1980) also used a sort-recall task and the metamemory questions corresponded to those given by Salatas and Flavell (1976). Metamemory questions were presented either before or after the memory tasks, forming the experimental and control conditions respectively. Metamemory was found to be correlated with strategic behavior in this study, but the reason for this effect was due to the inclusion of fourth graders and high school students in addition to first-graders. Within the group of first-graders, 50% showed adequate memory knowledge, which is the same proportion as in the study of Salataas and Flavell (1976). However, in contrast to Salatas and Flavell's (1976) study, fewer than half of the knowledgeable first-graders in the experimental condition spontaneously used clustering strategies. Nevertheless, in both studies, first-graders were found not to have well developed knowledge of the facilitative effect of grouping, and metamemory did not correlate with strategy-use for first-graders. The study of Wimmer and Tornquist (1980), on the other hand, did suggest that for children age 10 or above, a close relationship exists between metamemorial knowledge and behavior in the sort-recall task.

The age of emergence of a stable metamemory-memory behavior relationship has been shown to be variable, depending on the nature

of the stimuli. Corsale and Ornstein (1980) used semantically unrelated stimuli with third-graders and seventh-graders who were assigned to one of three instructional conditions. One was meaning oriented sorting, the second was sorting for later recall and the last was a combination of both. As predicted, the instructional conditions did not affect the performance of the seventh-graders. On the contrary, third-graders in the recall condition performed significantly worse than those in the other conditions. Furthermore, third graders in the subsequent metamemory interview did not know when it is appropriate to use an organizational strategy although they were aware of the utility of the strategy.

A number of studies investigated the relationship between metamemory and memory behavior across several related memory tasks (e.g., Cavanaugh & Borkowski, 1980; Best & Ornstein, 1979). Cavanaugh and Borkowski's (1980) study included all fourteen metamemory subtests developed by Kreutzer et al. (1975). Children from kindergarten, first, third and fifth grades were presented with the metamemory subtests and then were tested on sort-recall, cognitive cueing and alphabet search. Partial-correlations controlling for age revealed a modest correlation between metamemory and measures of recall, input organization and output organization. However, in the analysis of developmental trends, the correlations among variables dropped significantly. Specific memory knowledge was significantly related to memory behavior only for the fifth graders. No support was found for close metamemory-memory behavior relation involving both general and task specific metamemorial knowledge.

Subtests which measured specific metamemorial knowledge failed to correlate with memory measures. Of the entire metamemory battery designed by Kreutzer et al. (1975), story list, preparation object, retrieval event and rote paraphrase were shown to be the most sensitive measures. Cavanaugh and Borkowski (1980) speculated that the lack of metamemory-memory relation centres on the boundary conditions which limit the possible contexts in which connections will occur. Another explanation is the use of organizational strategies may be automatic, which does not require the activation of metamemorial knowledge.

Best and Ornstein (1979) gave third and sixth graders three trials of sort-recall with semantically associated list or a semantically unrelated picture list. In the test-trial, children of both conditions were given sort-recall tasks of semantically unrelated stimuli to examine the influence of previous experience. After the memory test, metamemory was assessed with a battery of questions. A behavioral measure of metamemory using peer-tutoring of first-graders was also used. The results showed that the prior experience with related or unrelated material influenced the sort-recall performance of third graders but not sixth-graders. The metamemory interview did not correlate significantly with the memory performance of third-graders and the correlation was also moderate for sixth-graders. However, the behavioral measure of metamemory was more closely related to recall. The two measures of metamemory did not correlate with each other.

The two studies (Cavanaugh & Borkowski, 1980; Best & Ornstein, 1979) seem to cast doubts on the validity of interview data for younger children. However, a similar study (Best, 1981) which used a simulated peer tutoring task did not detect any metamemory-memory relationship. Perhaps, metamemory is not well developed in younger children; in the peer-tutoring measure of Best and Ornstein (1979), what was tapped might not be fully conscious knowledge of metamemory.

Some studies used reported strategy use as an indicator of metamemory (e.g., Pressley & Levin, 1977; Waters, 1982). Paired-associate learning tasks were used in these two studies. In the study of Pressley and Levin (1977), the children reported the strategies used immediately after the presentation of the paired-associate stimuli. Their reports were used as the basis for classifying them into rehearsers, elaborators or mixed-strategy users. As predicted, strategy change correlated with age. The proportion of elaboration-users increased between grades 5 and 9, and rehearsers decreased between these two levels. The effect of strategy was also significant, indicating that elaborators recalled more than rehearsers at all grade levels. Also, fifth-graders who were elaborators outperformed ninth-graders who did not report sophisticated strategies.

Waters (1982) used a similar procedure and additionally assessed the judgment of effectiveness of four strategies which were reading carefully, rehearsal, visual elaboration and verbal elaboration. Eighth and tenth-graders formed the sample of this

study. Metamemory was significantly related to strategy use and memory performance across age groups. Verbal or visual elaboration correlated with better recall performance. Experience with the task affected the response in metamemory, in comparison with children in the control condition who only received the metamemory questions. Most experimental subjects identified elaboration as the most effective strategy. Only one-fourth of the control eighth-graders and one-third of the control tenth-graders did similarly. Also elaboration was most effective with tenth-graders.

In the study of Schneider (1986), developmental shifts in organization of words and deliberate strategy use were investigated. Second and fourth grade children were presented with word lists which were factorially combined in terms of interitem associations and category-relatedness. The task was a modified sort-recall task in which the children were given a sorting period and a studying period. Both sorting and studying strategies were recorded. Deliberate strategy use was also assessed by self-reports. General and task-related metamemory was examined with two measures. The former was tested with six items, five of which were items from three of Kreutzer et al.'s (1975) subtests: preparation object, retrieval event and rote paraphrase. The sixth item assessed the knowledge of utility of retrieval cues. The second, more task-related metamemory questionaire required subjects to compare the difficulty of two word lists, one consisting of clusterable, the other non-clusterable items. After watching a videotape demonstrating four memory strategies (rehearsal, grouping, naming and looking), the children

were given a comparison task and asked to state which strategy was better for the recall of a picture word list. After the comparison trials, the children were asked to rank order the four strategies according to their efficacy.

The results of this study suggest that the younger children demonstrated less clustering during recall when interitem associativity was low. Effective studying strategy use was related to perfect sorting, while non-systematic studying strategy was related to non-sorting, which suggests that children who sorted spontaneously understood the value of the strategy. General metamemory was more correlated with second-graders' strategy use and recall than task-related metamemory. Both components of metamemory were not significantly correlated with their judgments of perceived efficacy of memory strategies. As for the older subjects, the components of metamemory were related; both general and task-related metamemory were important predictors of strategy use and recall. Also, task-related metamemory predicted judgment of strategy efficacy in the older group. The evidence in sum, suggests that second-graders were less advanced in strategy use than fourth-graders, and their metamemory judgments were inconsistent.

The issues of test-retest reliability, internal consistency and construct validity on metamemory measurements were addressed by Kurtz, Borkowski, and Cavanaugh (1982), especially with regard to the use of qualitative report data. Two experiments were carried out to investigate the issues. The first experiment was to investigate reliability and internal consisitency. Fifty-five second graders

were given a metamemory battery. Four subtests were selected from Kretuzer et al.'s (1975) metamemory interview: story list, preparation object, retrieval event and rote paraphrase. The memory-monitoring task was adapted from Levin, Yussen, DeRoss, and Pressley's (1977) which assessed knowledge of short-term memory capacity, especially the ability to adjust recall estimates in relation to a prior recall experience. The last two subtests assesssed children's knowledge about input/output processing strategies. One was concerned with the awareness of familiarity of subtest matter in the allotment of study time. The serial recall measured the ability to match output demands with input strategies. Only the story list and memory monitoring failed to correlate significantly with the other five subtests, excluding serial recall. The split-half reliability was moderately high, and the test-retest reliability of the composite metamemory score was also moderately high.

In the second experiment, construct validity was investigated through the training paradigm. Children in the experimental condition were given training of an elaboration strategy to aid paired-associated learning. A significant difference was found between groups. Children in the experimental group were then classified as strategy users and non-users in the maintenance task. Recall was significantly different in favor of the strategy-user group for maintenance and generalization.

The findings indicated that the reliabiltiy of metamemory assessment would be acceptable if a composite score was used. Kurtz

et al. (1982) suggested that increasing the number of items in each subtest, clarifications in instructions and scoring, and revisions made to cover broader representation of memory phenomenon will likely lead to higher reliability and greater internal consistency. The second experiment strengthened the construct validity of metamemory by demonstrating that strategy training improves performance differentially, depending on the extent of prior metamemory knowledge. Also metamemory was a better predictor of memory processing than general intelligence in this study. The results of this study pointed to the possible usefulness of the concept of metamemory in explaining production deficiencies of strategies.

The studies reviewed indicate that metamemory (in particular knowledge of strategy use) is not developed in children in third grade and below. Although young children might be underestimated by measures such as interview, task-related measure and self-reported strategies seem to be viable and valid measures. It seems that metamemory could be measured reliably if a convergent approach was adopted, and construct validity was demonstrated in a training, maintenance paradigm as well as in demonstrations of strategy use.

Summary

This part of the literature review covered several theories of memory difference and development, and other related issues. One theory is that of Flavell and his colleagues (e.g., Flavell, 1971; Flavell & Wellman, 1977) which suggests four components, namely,

basic processes, general cognition, strategies and metamemory. Brown's theory (e.g., Brown, 1975, 1978) consists of similar ideas and its more recent emphasis is on executive processes, apart from the knowledge aspect of metacognition. There are also a number of more elaborate definitions of strategy. Pressley and his colleagues (Pressley et al., 1985) proposed a more detailed model of the metamemory of strategies. All these theories are based on similar assumptions, in contrast to the theory of Chi and others (e.g., Chi & Rees, 1983; Chi & Ceci, 1987) who suggested domain specific knowledge as the source of memory differences.

The organization of semantic memory was reviewed, according to the structural approach and qualitative approach, as well as its use as a strategy. Seriation, primacy, recency, priority and clustering are all forms of organizational strategies. Another strategy extensively reviewed was elaboration which is related to knowledge reconstruction and its effective and spontaneous use is relatively late in development. Lastly, the issue of metamemory-memory relationship was discussed. The literature suggested that a moderate relationship exists between metamemory and memory and a developmental trend is present in metamemory. Different procedures investigating strategy and metamemory, and issues of reliability and validity were reported.

Visual Short-Term Memory of the Deaf

Studies of the visual short-term memory of hearing-impaired subjects can be classified as in pursuit of certain primary codes or

strategies. These are either the search for alternative visual coding (as deficient articulatory coding is obvious in the deaf); comparison of efficiency in sequential processing relative to spatial (or configurational) processing; effects from presentations of stimuli (sequential or simultaneous) on performance; or the demonstration of certain common but modified characteristics of rehearsal in the context of the code used by the deaf.

Visual Code and Kinesthetic Code

Two very early studies on the visual short-term memory of the deaf confirmed their superior performance. Mott (1900) examined the memory of deaf children for objects and arbitrary collections of letters. The deaf children were found to be superior to the hearing controls in the visual memory tests. Blair (1957) found that the deaf were superior in the Graham-Kendall memory for Designs Test and also in the memory for lip and hand movement.

Conrad and Rush (1965) and Conrad (1970, 1972) found that deaf subjects showed a different pattern of letter confusions from normal hearing subjects in recall of visually presented letters. These studies suggested that visual shape might have been important in the codes used by the deaf.

Conrad's (1979) study explored the facility of a code other than a phonetic code. Deaf children presumably using a phonetic code and another group of deaf children who probably used a shape code were compared. Children using visual imagery recalled homophonic words as well as children using phonetic code in recalling

non-homophonic words. This was interpreted by Conrad (Conrad, 1979) that sequential order can be supported by visual imagery.

Locke and Locke (1971) used a procedure similar to that of Conrad and Rush (1965) for analyzing the nature of recall errors. The pairs of consonants to be memorized were either phonetically similar, visually similar or dactylically similar in American finger-spelling alphabet. They found that hearing children predominantly confused alphabetically similar letters, deaf children with assessed unintelligible speech predominantly confused dactylically similar letters, and deaf children with intelligible speech had confusions which fell between those of the other two groups.

Thomassen (1970) used a memory span paradigm to test whether the difference in the recall of acoustically similar and dissimlar items was absent in the deaf groups. He found that hearing subjects recalled less of the like-sounding lists than of the mixed lists, but no difference was found for the deaf. It might be inferred that deaf children were not using a phonetic coding strategy.

Chen (1976) studied the way deaf subjects code printed words. The hypothesis to be tested was that profoundly deaf subjects would show no difference in their detection of silent and pronounced "e's" as they would have little or no acoustic image. The hypothesis was confirmed. Hearing subjects missed almost twice as many silent "e's" as did the deafest groups with hearing loss greater than 80

decibels. The results of a hard-of-hearing group fell between these two.

Sipos and Arochova (1975) presented matrices with letters from an acoustically similar and dissimilar alphabet for 5 seconds to normal and hearing children. While the difference in the number of errors between the acoustically similar and dissimilar alphabets proved significant in the hearing subjects, it was not significant in the deaf. The error matrices indicated a systematic source of errors and different pattern for hearing and deaf subjects.

There is also some contrary evidence to the superior visual memory of the deaf. Carey and Blake (1974) tested a group of deaf and normal children on their ability to report letters, shapes and nonsense figures from a tachistoscopic presentation. Deaf subjects performed worse than the hearing subjects on the recall of figural information. However, there was no difference between the groups on position information and letter confusions were primarily visual in both groups.

Nevertheless there seems to be more evidence on the superior visual memory of the deaf. Some other studies have more thoroughly investigated the specific coding skills of the deaf. Flathouse's (1973) study involved four groups of 10 deaf children. Each recalled lists of visually presented words for the purpose of comparing the effectiveness of the alphabet coding strategies used by the groups. Each group was assigned an experimental condition, which was one recall strategy. The control group was free to use whatever recall strategy was preferred. Analysis of the data showed that of

the four groups, the sign group recalled significantly more words than the other three groups. Thus the hypothesis that subjects would perform better under the experimental condition that was most consonant with their primary mode of communication was confirmed. Results also supported a memory coding system based on gestures. A significant interaction between groups and words recalled by position with the "sign and say" group was also found. This group showed a superior recall of words in the later serial positions.

MacDougall (1979) carried out an experiment with two groups of deaf and hearing subjects, aged 10 to 12 and 15 to 18 who were required to recall letters of the alphabet presented in two different type scripts. The young deaf group relied predominantly on visual coding, whilst the older deaf group relied only partially on visual coding. Also the actual error confusions differed for the two groups. The older deaf group had relatively more acoustic errors than the young deaf in both conditions. Less similarity in the error patterns for both conditions in the older deaf group suggested that these subjects may actually perceive or attend to different visual features than the younger subjects.

Most of the errors for the young deaf group were visual, whereas in the young hearing group there were almost equal number of visual and acoustic confusions. The older hearing subjects tended to make more visual confusions than the young hearing subjects. Macdougall and Rabinovitch (1971) had suggested that the reliance of young deaf subjects on visual coding may have definite implications for the important problems of reading and writing. The fact that

older deaf subjects apparently use auditory memory to a greater extent than younger deaf subjects indicates that their memory development is exactly the reverse of the hearing subjects who develop from auditory to auditory-visual coding. There is also the possibility that the type of visual processing used by deaf and hearing subjects is in fact different.

Poizner, Bellugi and Tweney (1981) pursued the exploration of recall of signs by running three experiments. Experiment 1 compared short term memory for lists of formationally similar signs with memory for matched lists of random signs. Just as the acoustic similarity of words interfered with short term memory for word sequences, the formational similarity of signs had a marked debilitating effect on the recall of the sequence of signs. In the second experiment, the authors evaluated the effects of semantic similarity of signs on short-term memory. Semantic similarity only produced a weak, adverse effect on the short-term recall of sequences of signs. In the third experiment, the effect of iconic value of signs on short-term memory was studied. The results showed that greater iconicity had no reliable effect on recall.

Shand (1982) extended the investigation of Poizner, Bellugi and Tweney (1981) to examine the possibility of phonological coding and the coding strategies of congenitally deaf signers when stimuli consist of printed words rather than signs. Lists of phonologically related words and cherologically related signs were presented to eight profoundly deaf college students. The results showed that cherologic code was the principal basis employed for remembering ASL

signs and also there was a propensity to code lingusitic stimuli (i.e., words) cherologically.

Effects from semantic influence are also present apart from visual influence as demonstrated in the study of Frumkin and Anisfeld (1977), who conducted three experiments with 68 deaf elementary and high school students. False-recognition errors served as an index of memorial coding. In the first experiment, the items were printed words. Results showed a false-recognition effect for both semantically related words and orthographically similar words. In the next two experiments, subjects viewed a series of manual signs on videotape. In these experiments, there was a false-recognition effect for signs related semantically and for signs related cherologically.

The studies reviewed so far were preoccupied with the distinction between a visually or kinesthetically based code and an acoustically based code in memory representation. The studies to be reviewed in the following section also investigated this distinction.

Rehearsal Phenomena and Kinesthetic Coding

A number of studies also examined the effects of kinesthetic coding via manual signing on the characteristics of rehearsal which are associated with repetitive articulatory feedback, such as primacy and recency effects. Ronnberg, Ohngrea and Nilson (1981) evaluated memory performance in 12 deaf adult subjects, and 12 hearing adults served as the control group. A standard free-recall learning procedure with visually presented verbal material was used.

Deaf subjects exhibited superior recall performance for recency items when compared to the normal group. It was argued that since deaf subjects have acquired visual skills that emanate from their daily activities, there is a relationship between the use of visual skills and recall performance.

Wallace and Corballis's study (1973) investigated the short-term memory processing in orally and manually trained deaf children, as well as hearing controls. Two experiments were administered. The subjects attempted written recall, both immediate and delayed, of 4 and 5 letter sequences presented visually. The results showed not only that the deaf were inferior to the hearing, but that they encoded verbal material differently. Both deaf groups made extensive use of visual coding with 4-letter sequences. The evidence also suggested with 5-letter sequences, the orally-trained group used acoustic as well as visual coding. The manual group showed no evidence of acoustic coding, but probably made some use of a finger-spelling code. The visual confusions for both deaf groups were clearly not perceptual as subjects always wrote down the letters correctly during the presentation in the delayed recall experiment. These results confirmed the existence of a visual memory code for letters beyond the level of perception and iconic storage. In the delayed recall experiment, the manual deaf group was clearly superior to the oral deaf group.

Wallace and Corballis (1973) brought up the conjecture that there may be no intrinsic distinction between sensory memory and primary (short-term) memory in terms of the dimensions or modalities

that can be involved. They suggested that a more important distinction is between sensory and motor memory. Rehearsal may be essentially motor, in that it implies the recursive activation of information "from within". In remembering sequential material, normal hearing subjects would make use of articulation, whether overt or covert, but for the deaf who have been trained in manual communication, finger spelling may provide an effective alternative.

Bellugi, Klima and Siple (1975) studied the errors of recall in American Sign Language (ASL). They asked two groups of eight subjects each, one of hearing students, the other of deaf students who had learned ASL as a native language to participate in a recall experiment. Stimuli for the hearing subjects were word lists and for the deaf, the stimuli were sign lists. The authors found similar curves of serially ordered recall for both groups, but the memory span for signs for the deaf was one item shorter than the hearing subjects in words. The authors explained this difference by the smaller primacy effect found among the deaf; the rehearsal of the signs at the beginning of the list takes more time than that of words. The errors of the deaf subjects almost all showed visual similarity with the sign stimuli. For a stimulus sign articulated with two hands, the substitution in recall had the same number of hands involved. Further, the majority of the errors preserved the parameter values of the sign stimulus except one, thus creating minimal pairs in distinction.

Liben and Drury (1977) examined the rehearsal strategies in deaf children. It was hypothesized that deaf children might not have

readily available labels with which to rehearse the stimulus items. Several sets of stimulus materials were used. One set was highly familiar animals, the other was drawings of nonsense forms, the third set was letters written in lower case print, the fourth consisted of the same letters, but with pictures of the manual alphabet. During the test, the deaf children demonstrated high levels of overt activity in labeling and memorizing the nonsense forms. The serial learning curves showed strong primacy effects which are traditionally attributed to rehearsal strategies.

Swanson and O'Connor (1981) studied the primacy effect on recall of deaf children. A sample of hearing and deaf children were divided into five groups, matched on chronological age, IQ and degree of hearing loss. Deaf children were randomly assigned to one of three conditions: named-enforced use of finger-spelling, named-prohibited use of fingerspelling and unnamed-prohibited use of fingerspelling. The stimuli were six nonsense random shapes. Immediately after the training session, each child was tested with a probe-type memory task procedure. Significant differences were found between groups: hearing subjects in the named condition versus deaf subjects in the unnamed condition, deaf subjects in the condition of named-prohibited use of fingerspelling versus deaf subjects in the condition of unnamed-prohibited use of fingerspelling and deaf subjects in the condition of named-enforced use of fingerspelling. Results indicated that both primacy and recency positions account for the significant serial position main effects. For the deaf-unnamed condition, there was an ostensible lack of primacy effect. The

comparable performance of deaf and hearing children as a function of vocal or dactylo-kinesthetic naming was consistent with Liben and Drury's study (1977), in which primacy effects were found for deaf children. Swanson and O'Connor (1981) suggested that primacy effects in serial learning curves may be attributable to processes other than rehearsal, that is verbal and dactylo-kinesthetic encoding.

Dodd, Hobson, Brasher and Campbell (1983) studied deaf children's recall of word lists presented in different modes. In the first experiment, both the deaf and normal hearing teenagers exhibited more recency effect in their recall of lip-read lists of digits than in their recall of graphically presented lists. The result indicated that recency effects are not restricted to auditory perception or processing. Experiment 2 studied the effects of phonological and non-phonological suffixes on 10 deaf good articulators and 10 poor articulators' recall of lip-read lists. The two groups performed identically, whereas the phonological suffix impaired end-of-list recall, it did not affect recency. In experiment 3, the deaf and hearing subjects exhibited enhanced accuracy of end-of-list recall for moving handshapes as compared with static handshapes. The authors concluded that deaf subjects did not differ in the way they remembered the visual stimuli presented, and that lip-read lists were coded phonologically by deaf subjects regardless of their articulatory skill. Movement features were said to have enhanced recency effects in the recall of visually presented lists for both deaf and hearing subjects.

Unlike the above studies which primarily investigated basic rehearsal phenomena associating with kinesthetic coding, Bebko (1984) studied the rehearsal strategies used by deaf children in terms of efficiency and the pattern of emergence of spontaneous use across ages. Two groups of deaf children, 5 to 15 years old with severe to profound hearing loss, educated via aural/oral method or total communication method were tested with sequences of colors in the base condition. Behaviors of verbal or manual rehearsals were observed and the subjects were classified as either producers or non-producers of spontaneous rehearsal. The spontaneous rehearsal of both deaf samples was found to emerge later than the hearing sample's of another experiment (Bebko, 1979). Rehearsal emerged at age 7 to 8 years in hearing children previously tested, but at 10 to 11 years for the oral deaf group, and 12 to 13 years for the total communication group. The difference between the deaf samples must be taken with reservation, since there were only three subjects at the age range in the oral group. Rehearsal of the hearing was more effective in recall mediation, while no differences on recall were found between the deaf groups. Also there were more borderline deaf producers, implying that the rehearsal of the deaf was less efficiently implemented. However, in the condition when rehearsal was prevented or induced, the deaf recalled as well or better than the hearing. The results of the study suggested that it is more important to assess spontaneous and instructed strategy use; the lag in the emergence of spontaneous rehearsal for both deaf groups

suggested that the timing of intervention is more important than the modality of intervention.

In sum, basic rehearsal characteristics were found with the use of cherological or kinesthetic encoding. The issue of more complex strategy use or its development among deaf children has not interested researchers as much as the issue associated with auditory deprivation, which is temporal processing. This topic will be reviewed next.

Spatial versus Temporal Processing of the Deaf

The issue of the the nature of information processing of the deaf is explored in the present section. Since, in studies previously reviewed, it is found that the input modality is predominantly visual for the deaf, particular concerns have been raised in regard to the effectiveness of their temporal or sequential processing.

Pintner and Paterson (1917) had assumed that "visual imagery" would compensate and take over the role of the impaired auditory function. However, their findings indicated that the visual digit span of the deaf subjects was much less than the hearing. They then concluded that the "visual center" failed to take over the function of the "auditory center".

Pollard's (1977) study evaluated the effectiveness of deaf and hearing subjects in processing visual information presented spatially and temporal-sequentially. The stimuli were alphabet letters arranged as 4-letter words and pseudowords. Results

indicated that hearing subjects were superior to deaf subjects in processing information regardless of presentation mode. Both deaf and hearing subjects performed best in the spatial mode. The results were interpreted as lack of support for any compensation effect for processing visual temporal-sequential information.

Harris and Arnold (1984) extended Pollard's study (1977) to test the sequential strategies of deaf subjects of lipshapes, handshapes, as well as letters. The stimuli of lipshapes, handshapes and letters were presented to subjects in simultaneous presentation and successive presentation. Subjects included partially hearing, profoundly deaf and hearing individuals. Results showed a significant difference between the three simultaneous tests with the scores increasing from lipshapes, through handshapes to letters. In contrast, there was no significant difference between the three sequential tests. There was a significant difference between the simultaneous and sequential tests of lipshapes for both the partially hearing and profoundly deaf subjects. As for the hearing subjects, there was a significant difference between the sequential and simultaneous tests of letters. Although the profoundly deaf had the lowest scores in sequential tests, the general pattern of the two hearing-impaired groups was very similar to the hearing controls. Neither the partially hearing nor the profoundly deaf were significantly better at remembering sequences of static lipshapes than the hearing. Handshapes presented simultaneously were easier for the hearing-impaired to remember. The subjects in this study were orally trained, while a few of the partially hearing subjects

had some knowledge of signed English. For the partially hearing subjects, there was a significant correlation between memory for sequential handshapes and comprehension of signed English. Harris and Arnold (1984) concluded that in general there was no evidence of any compensation in the visual memory of the hearing-impaired, nor were they deficient in sequential skills which were presupposed by Sechenov (1878) as developing from auditory experience.

O'Connor and Hermelin conducted a series of experiments to investigate the hypothesis that cognitive or perceptual deficiency may impede children's evocation of relevant mental representation, thereby leading to different processing codes. O'Connor and Hermelin (1972) asked deaf, blind and normal children to report the " middle" one of three visually or auditorally presented digits. These were successively presented either through three speakers or in three display windows, so that the sequential middle was never central from a spatial point of view. The main finding was that input modality induced either spatial or temporal coding. The organization of visual items for the deaf subjects was predominantly spatial, since the spatially central digit was chosen most of the time.

The next study employed a different procedure; O'Connor and Hermelin (1973) presented digits successsively in different spatial locations, so that left-to-right order never correponded to the first-to-last order if presentation. Eight- to eleven-year-old deaf children consistently used the spatial order in immediate recall. In contrast, the eight-year old hearing children used the temporal order in recall. The same children also participated in a recognition

task. They were shown two sets of numbers, one of which corresponded to the spatial order, or the temporal order of the initial display, while the other set was in random order. The hearing children chose the temporal order significantly more than the spatial or random order, while the deaf children consistently chose the spatial order rather than the other two orders.

In another study (Hermelin & O'Connor, 1973), 10- and 12-year-old deaf and 8- and 11-year-old hearing children were given a recognition task of three visually presented digits in two conditions. Three digits were presented successively in three windows, with spatial temporal orders incongruent to each other. The recognition display showed digits one after another in one window below the other windows. The task was to judge whether the two presentations were the same or different. The hearing children attributed sameness only when the temporal orders corresponded. One half of the deaf children judged according to the spatial order. The remaining deaf children had a temporal response set like the hearing children. In the second condition, the one window display was presented first, and the reults obtained were similar to the first condition. It seemed that for some deaf children, left-to-right order was extremely salient, so that the left-to-right order was considered to be equivalent to the sequential order in the one window display.

Hermelin and O'Connor (1973) suggested that among the deaf, there are differences in their perceptual orientation. The researchers suspected that deaf children who preferred to encode in

spatial order would differ from deaf children who preferred a temporal order. It was hypothesized that deaf children with a spatial preferrence had not yet developed adequate articulatory skills as compared with deaf children with a temporal preference. However, no difference was found between the two groups of deaf children on articulatory skills nor on memory for rhymed words.

It was then posited that the visual coding might lack the unidirectional character of a linguistic one (O'Connor & Hermelin, 1976). The authors hypothesized that reversed recall of visually presented material might be easier for subjects using visual images. Twenty-four deaf and 24 hearing 14-year-old subjects were matched on forward letter span, and were tested for the backward recall on six item letter series. The hypothesis was confirmed for the order but not for item errors.

Beck, Beck and Gironella (1977) replicated O'Connor and Hermelin's (1973) experiment. In Beck, Beck and Gironella 's (1977) experiment, a group of hearing-impaird and normal hearing children were tested. Three digits were presented and the spatial and temporal order of the numbers were always incongruent. The results of recall showed that the two groups of subjects did not differ in the preference of spatial as opposed to temporal order. One possible confounding factor of the study may be due to the inclusion of hard-of-hearing subjects in the sample who would be more similar to the hearing children.

Lake (1981) reasoned that deaf children have developed a spatial perceptual set out of necessity, since spatial information is

more accessible than temporal information. Another argument is that deaf children choose to ignore temporal information although they have the encoding skill for it. This question of perceptual set was investigated in the first experiment, which was similar to the one of Hermelin and O'Connor (1973). The results showed that hearing children had a temporal set, whereas the response of deaf children was more heterogeneous. Forty-five percent of deaf children at Time 1 showed a temporal set, and 79% at Time 2 had a temporal set. Also 41% of the deaf children could not be classified as having either perceptual set at Time 1. At Time 2, this proportion dropped to 10%, which indicated practice led to more consistent performance. Most of the children who had equally high same responses to temporal and spatial trials also showed a high numnber of responses to random trials. It seems that these children were guessing or reponding to irrelevant dimensions. Age was found to be related to the likelihood of processing in a temporal set. Though it could not be concluded that deaf children showed a deficiency in temporal processing, the reason behind the bias toward spatial set of some deaf children remained unclear.

The results of a sub-study conducted with forty hearing-impaired students in the research of Booth (1984) suggested that the rate of presentation of incongruent temporal/spatial presentation was a factor influencing responses. An increased rate was more able than a slower rate to distinguish between hearing-impaired students who responded temporally and those who responded spatially.

Clark (1977) investigated two processes, serial order processing and configurational analysis, with the aim of discovering whether young deaf children demonstrate a preference for, or greater facility with either one or the other strategy. A sample of profoundly, prelingually deaf subjects was matched with subjects of normal hearing on intellectual ability. The "Knox Cube" subtest from the Arthur Point Scale of Performance Tests was used to measure serial order processing. The Raven's Colored Progressive Matrices was used to measure configuational analysis. Results showed that the deaf subjects performed most competently on the configurational aspects than by serial order. Item analysis revealed remarkable similarities between the deaf and hearing groups on the instrument used to measure configurational analysis. Results suggested that the development of configuratory processes among the deaf is similar to hearing children in general. However, the ability to retain and reproduce sequentially presented stimuli was significantly depressed among the deaf subjects. Clark suggested the reason for the observed deficit in serial processing to be restricted exposure and limited experiences in dealing with serial order.

Belmont, Karchmer and Bourg (1983) studied the temporal and spatial sequence in deaf children's recall. They administered to 16 prelingually profoundly deaf and 16 hearing children a short term memory task of recall of the temporal or spatial sequence in which four letters were presented. On initial free response trials, all hearing subjects and seven deaf subjects showed a temporal orientation. The remaining nine deaf subjects showed a spatial

orientation. On later trials, the subjects were instructed to take the orientation not previously taken. It was predicted that all groups would show substantial flexibility, but only the hearing group actually showed the predicted recovery. Recall response times indicated processing differences between the two deaf groups, even when stimulus presentation parameters were individually adjusted to tap each subject's optimum performance. It was concluded that individual differences in deaf children's initial orientations bear significantly upon differences in performance because of these children's relatively weak adaptative responses under challenging conditions.

Hanson (1982) investigated the speech-based and sign-based encoding of printed words by deaf native signers of ASL and their relation to sequential information. The first experiment conducted was an order recall paradigm, the second was a free recall paradigm. Three experimental sets of eight monosyllabic words were used; the words were either (a) formationally (in sign) similar, (b) phonetically similar, or (c) graphemically similar. For each of these sets, a control set of dissimilar words was constructed, matched for frequency of occurrence in written English. The subjects were a group of prelingually profoundly deaf college students and graduates and a control group of hearing subjects. The subjects were presented five words from one of the sets on each trial which were then followed by a probe word. The required response was to indicate the word that followed the probe word. Two kinds of presentation were employed, printed word presentation with the use of a

microcomputer and sign presentation on videotape. All subjects showed a performance decrement for the phonetically similar set compared with the control set. It was inferred that both groups of subjects were using a speech-based code in order recall. Consistent with many other findings, the deaf subjects performed worse than the hearing subjects in order recall. In the second experiment, it was found that the specific difficulty that deaf adults have is with retention of sequential information but not independent items.

In contrast to the findings of the studies discussed so far, two studies could not confirm the inferior sequential processing of the deaf; also issues related to the content material were raised. McDaniel (1980) contrasted performance in simultaneous presentation and that in sequential presentation, while Das (1983) explored two kinds of coding with a battery of tests.

McDaniel (1980) investigated the perceptual ability of deaf children employing both simultaneously and sequentially presented stimulus material. A series of 10 motion picture tests was administered to 43 deaf children and 56 hearing children. There was no significant difference between hearing children and deaf children on tasks which required memory for visual figural content. The evidence also did not support the contention that deaf children are likely to have more trouble with successive perception than with simultaneous perception. However, the figural content of the task might have induced the same process in both kinds of presentation.

Das (1983) conducted a study on the short-term memory of deaf children. The three objectives of the study were: to

investigate whether deaf children prefer spatial order to temporal order in free-recall condition, whether the preference for spatial order is maintained in a probed-recognition condition, and to seek the relation between individual differences in simultaneous-successive processing on the one hand and spatial and temporal memory on the other. Each subject was tested on free recall and probed recognition for measuring temporal and spatial-order information. The apparatus consisted of three rectangular windows for presenting slides of 36 familiar pictures from Peabody Picture Vocabulary Test. To test simultaneous processing, figure copying and Memory for Designs were administered, and for successive processing, auditory serial recall and digit span were used.

The results did not show any higher preference for spatial order than temporal order. Significant correlations were obtained between serial recall and temporal order recall, and between serial recall and probe recognition. However, the correlations between digit span and the two recall tests were very low. Das (1983) speculated that the two tests, digit span and serial recall, do not measure the same process in a deaf sample. The results concerning the simultaneous tests were not totally in support of the second test hypothesis. Only temporal probe recognition scores had a significant correlation with Figure Copying. Spatial order could not be significantly predicted by any of the simultaneous-successive tests. Das (1983) suspected that in the deaf, digits and words are processed differently, and that the coding of order information is not clearly understood. Further research on item and order recall of alphabetic

script and logograph was suggested. One comment about Das's (1983) study is that the results may not be as problematic as they seemed to him. In sign language, the signs for digits are overlearned information, and since the subjects in this study were in an institution where sign language is used, the coding of digits and rehearsal of digits would most probably have been done in a cherologic mode. As for serial recall and probe recognition, the deaf subjects might be using a specific strategy for dealing with English words. Another point is the test battery used to measure simultaneous processing may be in fact inappropriate for the construct.

Overall, although there were a few different findings, the consensus seemed to be that most deaf children have limited sequential processing ability. What will be reviewed in the following section is concerned with the effects of semantic structures and syntax.

Semantic and Syntactic Structures

A number of studies have investigated the wider context of semantic and syntactic influences. The latter includes studies of influences from both verbal and sign language syntax on memory.

Tweney, Hoemann and Andrews (1975) explored the organization of items in the subjective lexicons of deaf and hearing adolescents. Two studies were conducted to determine the amount of hierarchical structure present in the sorting of deaf subjects compared with the performance of the hearing subjects of the same

age. In the first study, semantic domains were chosen to assess the relative contribution of specific experiences to deaf persons' lexical structures. Three domains were used: common noun words, line drawings corresponding to the noun words (to determine if there is a uniquely visual component involved in the structure of deaf subjects' lexicons) and words referring to sounds (for which deaf subjects should have limited or no experience).

It was hypothesized that if the thinking processes of deaf persons are as logical and abstract as those of hearing persons, then their subjective lexicons ought to reflect the same amount of hierarchical structure given that the stimuli are equally familiar to both deaf and hearing subjects. Thus the sorting data of common nouns and pictures ought to reflect the same levels of conceptual thinking in deaf and hearing subjects, while the sorting data for sound words ought to maximize the difference between the groups. Both the pictures and the nouns used in the first study were concrete and high in imagery value; the second study used two different word lists that were either very high or very low in imagery value as measured by the norms of Paivio, Yuille and Madigan (1968). The subjects were 63 severely and profoundly deaf adolescents and 63 hearing adolescents.

The results of the first study showed that there was no substantial difference between the deaf and hearing subjects in the sorting of nouns and pictures, while the two groups differed in the sorting of sound words. Results of the second study showed that there was significant difference due to stimulus type. The

differences between high-imagery and low-imagery items appeared much greater than differences between deaf and hearing subjects within any given word category. In the clusters of words made by the deaf subjects, the node values were lower than those of the hearing subjects, reflecting less commonality of meanings among deaf subjects. This difference was apparent particularly for low-imagery words. Nevertheless, the two studies implied that there are no qualitative differences between the lexical structures of deaf and hearing persons except when the extent of experience with the lexical items is a critical factor.

Koh, Vernon and Bailey (1971) studied the free recall performance of prelingual deaf subjects to examine the influence of an impoverished acoustic-lingusitic system. A group of deaf subjects and a group of hearing subjects were tested. They were also equally divided into two groups by age and sex. Two word lists were used as stimuli, the uncategorized mixed word list and the categorized. Line drawings depicting the words were made into slides. Results showed that the older subjects recalled better than the younger, and the hearing recalled better than the deaf. There were no significant interaction effects for the recall of the categorized list. The negatively accelerated learning curves from the hearing and deaf groups were parallel. The intratrial retention interval applied to identify the primary memory words in the mixed list showed a significant difference between the hearing and the deaf, but there was no significant trend shown in the categorized list. Analysis of subjective organization was applied to all four groups, and the

scores of the hearing subjects were superior to those of the deaf subjects. Furthermore, stimulus category repetition analysis showed that the hearing subjects' category organization was higher than the deaf subjects' in both age groups, but the difference reached significance level only between the two younger groups. With respect to hierarchical clustering schemes, there was noticeable variability in the deaf subjects' schemes.

Fremer's (1973) study assessed the ability of hearing children in three grade levels and deaf children at three age levels in their memory of word lists that varied in their degree of contextual constraints. The findings on the number of words recalled suggested that the deaf children did not possess a fundamental grasp of the connectedness of language that is commensurate with their ability to recall unrelated words and their knowledge of vocabulary. Although they recalled the constituent words, they demonstrated only limited ability to profit from the language structure that permits clustering for hearing subjects. An analysis was made on the type of distractor selected. All groups except the youngest group made a greater proportion of same-form class errors for the three higher order lists than they did for the three lower order lists.

Deily's (1977) study was aimed at the comparative development of semantic and syntactic structures in deaf children and hearing children. The sample for the study consisted of congenitally, profoundly deaf subjects and normally hearing subjects in four age ranges. The syntactic performance of the deaf children in sentence recall was found to be different from that of the

normally hearing children. The errors of the deaf subjects were very likely to violate the rules of English to a much greater extent than the hearing children. It also seemed that there was no improvement in their syntactic performance over age. However, the semantic performance of the deaf children was found to be similar to that of the hearing children.

Liben, Newell and Posnansky (1978) conducted several studies to examine the deaf individuals' use of formational similarity of signs to organize long-term memory. Deaf adults were given several free recall tasks that contained formationally similar items. In the first study, a 16-item list in either a written or a signed mode was presented to the deaf subjects. Regardless of presentation or response mode, subjects showed evidence of clustering by semantic rather than by formational similarity. In the second study, the stimulus materials were modified to enhance formational similarity. The 16-item list was made up of four groups of four signs made at the same location of the body as well as with the same handshape. All subjects were given pre-test trials and after one week they were tested again. The subjects were given an explanation of the categorical nature of the test before the third test. The important finding was that there was almost complete absence of spontaneous clustering by formational similarity on the initial or the one week recall trials. The subjects showed high levels of formationally-based clustering on the final recall trial which followed an explanation of the categorical nature of the list. These

results suggested formational properties were not spontaneously used for organization in long term memory.

Hanson, Liberman and Shankweiler (1984) examined the coding ability of deaf children with the aim of addressing reading success in this population. This research compared the recall of strings of consonants that are phonetically, manually or visually similar with unrelated (control) strings. The deaf subjects of three grade levels were classified into good readers and poor readers, using reading achievement tests. The children were presented with four sets of letters and the response was to write the letters in the correct order. Good and poor readers were found to be differentially affected by the four stimulus sets. The performance of the poor readers did not vary significantly as a function of the stimulus. In contrast, the good readers' accuracy for the phonetically and dactylically similar sets was significantly greater than accuracy on the control set. Errors of the good readers also indicated it was a function of the stimulus sets whereas it seemed that the poor readers were responding randomly when they made an error. The difference between good and poor readers in the use of short term memory codes was also correlated with difference in serial recall ability. It was noted that the speech of the two reader groups was not significantly different. This suggested, according to the researchers, the speech abiltiy per se did not differentiate good and poor readers, but rather the good readers' more effective use of a short-term code based on linguistic features. The discrepant findings that the deaf subjects of this study benefited by a rhyming set in contrast to

other results (e.g. Conrad, 1972, 1979) was explained as resulting from different procedures, with limited stimuli for each set.

Lichenstein (1984) studied the recoding strategies of speech and sign as used by deaf students in representation of English surface structure in working memory (or short-term memory). Deaf students were asked in a questionnaire to memorize a sentence and then write it on the next page. Then they were asked if they had used sign or speech to recall the sentence. They were also asked to underline the words for which they had used signing or speech as recall strategies. For the students who had reported the use of signing, the majority of them reported a kind of "selected recoding" of the words in the sentences. Eighty-five percent of the content words were recoded as compared to 48% of the function words. The results for speech recoding were similar. Selective recoding strategies for speech were primarily found among students with lower speech index scores. For speech, 7% of the content words were recoded compared to 55% of the function words. A follow-up study (Lichenstein, 1984) obtained data both on the recoding of grammatical function words and for morphological suffixes. The results suggested there are specific psychological or physiological bases for these strategies. For both speech and sign codes, the tendency not to recode free functors was found to be associated with more limited working memory capacity. Students who were found to have more limited working memory capacity reported not having recoded many function words either to speech or to sign. For the speech recoders, it was found that the tendency not to recode morphological suffixes

was primarily related to a lower speech intelligibility rating. The failure of many deaf students to recode morphological markers to speech seems to be related to physiological characteristics of their internal speech.

Another study done on reading was by Treiman and Hirsh-Pasck (1983), which examined the recoding strategies of relatively successful deaf readers. The subjects were second generation deaf who learned ASL as a native language from their deaf parents. Hearing adults who knew ASL served as control subjects. Four experiments tested for the possibilities of recoding into articulation, fingerspelling, ASL or no recoding. The first experiment was designed to test the articulatory recoding in deaf readers. The subjects had to judge whether the sentences they read were correct in English. The results showed that deaf individuals performed equivalently on homophone and control sentences, indicating that deaf subjects did not identify words on the basis of their articulatory forms. The results in the second experiment showed that difficulties on similar articulation sentences relative to control sentences were statistically indistinguishable for the deaf and hearing groups. One suggested explanation was that the stimuli were confounded by visual confusion. The magnitude of the effect of Experiment 1 did not correlate with the effect of Experiment 2 for either hearing or deaf subjects. The third experiment involved the use of fingerspelling sentences. Although the deaf showed a slightly larger decrement than the hearing on similar finger spelling sentences relative to control sentences, the differences between the

groups were not significant. The fourth experiment used sign (ASL) sentences. The results showed that deaf subjects made significantly more errors on the similar sign sentences than the controls. This suggested that deaf readers used sign recoding. The subjects appeared to recode English into ASL despite the fact that very few spelling-sign correspondence rules exist. This disadvantage was apparently outweighed by the gains in comprehension and memory achieved by the use of their native language. The results also suggested that the very best deaf readers do not recode into signs.

Tweney and Heiman (1977) used a short-term free recall task in which nonsense gestures were included in either grammatically or randomly arranged strings of ASL signs. If grammatical structure does in fact, facilitate encoding of a sequence of signs, then recall of nonsense gestures should be facilitated as well as grammatical strings. Such an outcome would suggest that ASL structure is not relatively peripheral. The subjects in the study were deaf college students. Twenty-five 5-sign grammatical ASL sentences were selected and another set of randomly assigned 5-sign strings was constructed. The stimulus lists were then prepared by systematically replacing one sign from each sentence with either a nonsense sign or a finger-spelled CVC (consonant-vowel-consonant). The results supported the hypothesis that the presence of ASL structure contributes to the ease of processing. The authors concluded that the syntactic processes in ASL are "abstract" in a way which is independent of particular input or output channels, and that grammatical structure appears to derive from human cognitive

capabilities, rather than from specific characteristics of an input or output channel.

To test the hypothesis again, Tweney, Heiman and Hoemann (1978) investigated the performance of deaf subjects in a perceptual task. Grammatical ASL sentences, semantically anomolous ASL strings and lists of random strings were used as stimuli. Each set of items was presented on video tape to profoundly deaf college students who were fluent ASL users. Presentation was disrupted by use of a temporal interruption circuit which blanked the video screen twice per second, leaving the screen on for 50% of the total time. The significant result was the subjects reported more grammatical strings than the other two kinds. The same trend was found in a short-term memory task using similar stimuli, but without video disruption. The results suggested that the grammatical structure of ASL facilitates performance in the same way that English grammatical structure facilitates performances with auditory stimuli.

In general, the studies showed that syntactic structures of sign language are similar to those of verbal language in terms of the facilitative role in encoding. Although the surface structures are different, the linguistic functions are the same. The more capable deaf readers were found to be those who were able to capitalize on linguistic functions of both languages. The semantic structures of the deaf are similar to those of hearing individuals although attenuated. The next several studies to be reviewed are still preoccupied with the encoding process, and specifically the imaginal code.

The Role of Imagery

The effect of imaginal code was investigated in the deaf in comparison to that of the hearing in a handful of studies. Possibly, the extent of reliance on the imaginal code of the deaf would be different from the hearing, and the use of sign encoding might interact with the use of imagery.

Conlin and Paivio (1975) conducted two paired associate learning experiments of the deaf. Both experiments involved systematic variation in the rated "signability" and imagery value of words. The stimuli were paired-associate words of four categories : low imagery/low signability pairs, low imagery/high signability pairs, high imagery/low signability pairs, and high imagery/high signability pairs. In the first experiment, 30 prelingually deaf students and 30 hearing controls served as subjects. In the second experiment, subjects were 26 older deaf students and 26 older hearing students. Following the paired-associate task, the subjects were required to complete a strategy questionnaire. Two word lists were used in the second experiment on the subjects who were divided into two groups. For both experiments, results indicated that the recall performance of the hearing subjects was superior to that of the deaf. Recall was generally better for high-imagery than for low imagery pairs. The expectation that the facilitative effect of signability is restricted to deaf subjects was confirmed in Experiment I. The significant imagery by signability interaction indicated that the effect of signability depends on the level of imagery, when the pairs are high in imagery level. In the mediation reports, the deaf

subjects reported the use of image, sign and other strategies. Both hearing and deaf subjects reported the imagery strategy more frequently for the high-imagery pairs than for the low-imagery pairs.

Craig (1973) tested the "dual coding" hypothesis of Paivio (1971) by examining the effects of imagery on the performance of deaf, blind and normal subjects. It was assumed that the deaf encode information primarily in the form of nonverbal imagery, whereas the blind are likely to store information as auditory-motor representations. The subjects were 40 hearing college students, 20 blind adolescents and 20 deaf adolescents. The stimuli were 210 words selected from the Paivio, Yuille and Madigan's (1968) norm. Fourteen lists of high-imagery words or low-imagery words were constructed. Presentation of the stimuli to the deaf and their control group was done with the use of 16 mm film, while the stimulus lists were presented to the blind and their controls by a tape recorder. Results showed that the group and imagery level main effects were significant in both the normal-deaf and normal-blind comparisons. The normals as expected showed significantly higher recall than either the deaf or the blind. The normals and the deaf exhibited higher retention of high-imagery than of low-imagery words. According to the dual coding hypothesis, there is more efficient retrieval of the dually-coded high-imagery words than of the singly coded low-imagery words. Craig (1973) conjectured that, with regard to the deaf, high-imagery words have a higher probablity of being stored in memory, reflecting that the visual code is a primary available code. No imagery effect was observed in the recency

portion of the serial curves of the control groups and the blind. No differences between high and low imagery words in recency would occur unless the stimuli could not have auditory representation during the early stages of information input. This was the case for the deaf, there was a relatively larger difference between the two types of words in the recency position. However, overall, the deaf did not exhibit a larger relative difference in the retention of the two classes of words than did the normals.

Parasnis (1979) conducted a study which was a variation of Conlin and Paivio's (1975). The study was designed to investigate the influence of visual imagery on the processing and retrieving of signs and to test the relative efficacy of signs and word codes. It was hypothesized that if signs are processed like words, then the imageability of their referents will influence the processing and retrieval of information and thus a facilitatory effect of imagery should occur for both signs and words. However, if the visual-spatial nature of signs causes them to be highly encoded by the imagery system regardless of differences in the imageability of the underlying concepts referents, high-low imagery differences should not occur for signs. Secondly, the author hypothesized that information presented in signs should be retrieved better than words just as pictures which get highly encoded by the imagery system are remembered better than words.

Subjects were 40 congenitally deaf college students matched on English competence and 40 hearing fluent signers. The subjects were randomly assigned to four conditions of the experiment,

sign-sign, word-sign, word-word and sign-word. The word lists consisted of high imagery value nouns and low imagery value nouns. The list was videotaped into two formats: words and signs. The four conditions were constructed by varying the mode of presentation with the mode of retrieval. Each subject was given a learning trial, distraction task and free recall.

Results showed that there were significant main effects for group and for imagery. There was a significant imagery by condition interaction. It was mainly due to the recall of high and low imagery items on the word-sign condition which was significantly different from the other three conditions. The word-sign condition was different from the others in that no facilitatory effect of imagery occurred. There was no significant interaction by group, suggesting that when deaf and hearing subjects are reasonably fluent in both languages, there are not significant differences in their processing and retrieval of information from those languages. As there was no significant condition main effect, one possibility was that sign language is processed in a way similar to English language. The main imagery effect obtained in this study was taken as a confirmation of Conlin and Paivio's (1975) results with English words, inferring that signs are processed similarly. The particular lack of imagery effect on the word-sign condition was interpreted as due to the condition itself. It seemed that both hearing and deaf subjects employed a strategy different from the strategies used in the other conditions. It was suggested that it was harder to find an adequate match from English onto sign for low imagery words. The

absence of context also made it difficult to translate different shades of meaning.

Cornoldi and Sanovio (1980) also investigated the effect of imagery value and recall in deaf children. A free recall task was administered to 33 deaf children and 33 hearing children. The recall list was composed of nouns which had the same frequency value and varied with respect to level of imagery value, i.e., high, medium and low. Both groups showed significant improvement in performance with the increase of imagery value and number of recall trials. A significant interaction between group and imagery was found. It was observed that medium imagery nouns were recalled more easily by the deaf. The results supported Paivio's dual coding (1971) in general. However, the results indicated that deaf children made less use of the verbal system and greater use of the imaginal one. This was reflected in a much larger number of words imaginally coded.

Bonvillian (1983) examined the immediate and delayed free recall of visually presented English words to two groups of deaf adolescents and a control group of hearing college students. One group of deaf subjects was born of deaf parents and sign language was their first language. The other group of deaf subjects was born of hearing parents. The stimulus words consisted of an equal number of high imagery words and low imagery words. The value of imagery was based on the scale values of Paivio, Yuille and Madigan (1968). The words were further classified as having direct sign-language equivalents or not. There were altogether four different categories of words: high imagery words with sign language equivalents (high

imagery-signable), high imagery words without sign language equivalents (high imagery-unsignable), low imagery words with sign language equivalents (low imagery-signable) and low imagery words without sign language equivalents (low imagery-unsignable).

In the immediate recall condition, the order of performance was: the hearing subjects scored the highest, deaf subjects of deaf parents scored the middle and deaf subjects of hearing parents scored the lowest. In the delayed recall condition, the performance of the two deaf groups was not significantly different from each other. Both imagery and signability were important factors in the deaf subjects' recall, while only imagery was important in the hearing subjects' recall. In the reported mediation, more deaf subjects of deaf parents reported using signs as the most frequently employed encoding strategy than deaf subjects of hearing parents. The hearing subjects, on the other hand, often reported organizing the stimulus words into complex visual images or into sentences.

In general, these studies showed that there is a basic similarity between deaf and hearing individuals in the use of imagery when the imagery value of the stimuli is high. However, as there exists the problem of translation from words to signs, the question of whether deaf subjects in general or deaf subjects of hearing parents resort to using imaginal code more than the hearing subjects may be confounded by the extent of knowledge of either sign language or verbal language.

Summary

The existing literature on the memory of the deaf seems to be preoccupied to a large extent with the consequence of auditory deficit. It appears that the levels-of-processing model was in the background of these research studies; yet, a majority of them investigated the surface code in isolation of other levels of processing. A large amount of research was done with regard to the encoding mode and ability in sequential information processing. The research findings suggested that deaf individuals use a visual code; deaf individuals who know sign language also use a kinesthetic code. Although some deaf individuals are as able to process sequential information as hearing subjects, most research findings suggested that many deaf children have a bias towards using spatial processing. The effects of the formational properties of sign language have been investigated in relation to rehearsal phenomena, and some of the characteristics occurring in verbal rehearsal such as recency and serial position were also found in cherological rehearsal. The semantic structures of the deaf were found to be similar to the hearing, although less cohesive and restricted. Although English syntactic structures were not well developed in most deaf children, except the most capable readers, the influence of sign language syntax was found on recall, similar to the influence of verbal language syntax for hearing people. The recoding of English orthography into sign or speech was found to be selective and restricted by the working memory capacity, and the recoding into

speech was dependent on the facility in speech of the deaf individuals. Not much difference was found between the deaf and the hearing in regard to the use of imaginal code. Both the deaf and the hearing were shown to be facilitated by high imagery material and adversely affected by low imagery material. Only one study has investigated the time of emergence of spontaneous strategy use, and it was found that deaf children showed a lag in development when compared with hearing children.

In the next chapter, the present research methodology will be described. The research was an attempt to study different aspects of the memory of the deaf in an integrative manner, based on the major issues uncovered about their shortcomings in short-term memory. Also different theoretical ideas were borrowed in the total conceptualization.

CHAPTER III

RESEARCH METHODOLOGY

Purpose

The purpose of the study was specified as an investigation of the representation and performance of memory (i.e., encoding and retrieval processes) and metamemory ability of deaf students between late childhood and young adulthood. Firstly, the relationship between representation in encoding and retrieval performance was examined. Secondly, the study investigated the person variable (age), strategy variable (organization and elaboration), and task variables (types of task and task conditions) involved in retrieval performance and their interactions. Finally, the relationships among age, metamemory, short-term memory and long-term memory were also investigated. A number of memory tasks and a metamemory interview were used in the study; the rationale for their use and construction are explained below.

Rationale

The present research adopted a process approach which took into consideration the interplay of variables in the immediate situation, which induce information processing in the short-term or working memory. This process approach puts special focus on the spontaneous use of strategies, although its analysis was conducted mainly on the output, which would not have the flavour of ongoing behavior observation. The metacognitive views of Flavell (Flavell & Wellman, 1977; Flavell, 1971, 1976, 1977) and Brown (1975, 1978) were

implicit in this approach, and also the emphasis on the role of knowledge of Chi (Chi & Reese, 1983; Chi & Ceci, 1987) was taken into consideration. The knowledge dimension is in fact one component of the metacognitive view and what is commonly known as long-term semantic memory.

The level of semantic knowledge and English skill that deaf children possess is said to be affecting performance. Therefore, it is important for researchers to ascertain whether it is the properties of the knowledge base or processing strategies that are in question. To this end, the subjects were first assessed to determine their knowledge (or long-term memory) of English vocabulary. Stimuli of the other tests were taken from the same word pool. High imagery words are often words of the highest frequency in usage, and are also the words most likely known to deaf students. Since the deaf students' attainment of English reading level was known to be lower than hearing students (Conrad, 1979; Quigley & Kretschmer, 1982), the selection of word stimuli was restricted to this category. Moreover, abstract words might not have ready sign equivalents. Earlier pilot studies which included abstract words indicated that the deaf students have problems of comprehension on these words. The assumption underlying dual-coding and bilingual memory (Paivio & Desrochers, 1980) was adopted in regard to conceptual reference, though the entire theory was not accepted without qualification. It was assumed the imagery system which is part of world knowledge and the two languages (English and sign) are partially connected;

therefore the use of high imagery words as stimuli ensured a better chance of referential commonalities.

High imagery words were also used for the purpose of strategy facilitation, for in the view of Bower (1970, 1972), imagery produces a strengthening effect in the associative connections. With imagery effect maintained constant across words, the pairing of words in the paired-associate learning task was manipulated according to the dimension of typicality of script-like association, resulting in two task conditions. This manipulation was based on the ideas of J. Mandler (1979), Nelson et al. (1983), Rosch (1978), and Rohwer (1973) on script-like organization, event organization and prototypes of semantics. The target strategy in the free-recall task was the use of taxonomic organization. Although imagery value was held constant across words, a higher level strategy had to be employed in order to achieve optimal performance on free-recall.

The perennial issue of "deaf memory" is representation or memory code. This was investigated in the light of deliberate encoding, instead of being looked at as a fixed ability biasing the encoding process towards a spatial or temporal set. By deliberate encoding, it was meant that the encoding tasks required deliberate effort or strategy to encode the information, in this case both spatial and temporal information, given both a temporal goal and spatial goal in unambiquous instructional procedure. This procedure minimized the possibility of misunderstanding, and also the measurement criterion was not based only on overall performance score, but on the types of confusion made. Certain active strategies

were thought to be required by the encoding tasks, for encoding was not viewed as a basically passive perceptual process solely dictated by the intactness of the sensory organs. The performance on spatial/temporal encoding was seen in the whole context, by looking into its correlations with other memory and metamemory tasks as well.

The aspects of metamemory under investigation were aspects of declarative metamemory, following the distinction of Pressley et al. (1985). Four subtests from Kreutzer et al.'s (1975) interview were selected, with the procedures and wording modified, aiming at more clarity. A scoring criterion was constructed which rectified the vagueness of quantification of the original interview. The adopted subtests were: story list, study plan, retrieval event and opposites-arbitrary. Retrieval event was chosen because it was assumed to tap different levels of strategy use, from external mediation to internal mediation, and also retrieval event subtests had been repeatedly shown to be one of the three most valid subtests (Cavanaugh & Borkowski, 1980; Kurtz et al., 1982). The other subtests were included because they were thought to be indirectly related to the nature of the memory tests. Story list was also said to be a good predictor (Cavanaugh & Borkowski, 1980) and was related to the paired-associate learning tasks in terms of the propensity to use elaboration; study plan was related to free-recall since it examined the development of organizational strategies; and opposites-arbitrary was related to the paired-associate learning and free-recall tasks in terms of knowledge of semantic relationships inherent in the task content.

The "hardware" (Flavell & Wellman, 1977) or "architectural system" (Campion & Brown, 1978) of short-term memory or capacity was assumed to be measured by the digit-span test. Since rehearsal was a primary strategy necessary in all the memory tests, digit-span was also used as an indicator of the effectiveness of cumulative rehearsal over time, in other words sequential processing. Informal behavioral observation was used during the interpolated color-matching task, as a complementary technique to assess sequential strategies or non-sequential strategies. In a general way, increase of age was thought to be related with better performance and strategy use, although possibly the magnitude might not be the same on all metamemory and memory tasks and on all conditions.

Pilot Studies for Word Selection

A pool of words was developed for the present study to control for lexical complexity which is often a characteristic of longer words, as well as to control for frequency. Carroll, Davis, & Richman's (1971) compilation was preferred to Thorndike and Lorge's (1944) from which Paivio, Yuille, and Madigan (1968) chose their words for imagery rating. The corpus of words in Carroll et al's (1971) was thought to be more appropriate as it is more recent and selected from published material to which students from grades 3 through 9 are exposed. Since the norms were American, there might be some possibility of inappropriateness for Canadian school children; however, no similar extensive compilation had been done in Canada.

A total of 306 nouns, with either six or seven letters in spelling were first selected from the norms of Carroll et al. (1971). The frequency range of the 306 words was between 49.0 and 59.0 according to the Standard Frequency Index (SFI). The SFI is an indicator of the probability of the occurrence of a word type. This was derived from the estimated frequency-per-million tokens with an adjustment for the dispersion of frequencies over seventeen subject areas. An SFI of 40 indicates the probability of occurrence of once in a million tokens. Each unit of SFI represents an increase of about 25.9% in probability or frequency (Carroll et al, 1971). These chosen words were estimated to be within the comprehension range of grade 3.

Six university students whose native language is English were paid to rate the 306 words according to imagery value on a scale of 1 to 6, with 1 being the highest rating. They were asked to imagine the sight, sound, smell, feeling, texture or tactile sensation associated with each word and rate according to the strength of the imagined sensation. Three groups of words were subsequently chosen from the rated words.

Eighty were selected out of the 86 words which had either 100% consensus on rating 1 or combined 100% consensus on ratings 1 and 2. Some of the eliminated words were sound imagery words which would not be approapriate for deaf individuals. Another set of 40 words was chosen; these were words which had 83% consensus on rating 1, or combined 83% consensus on ratings 1 and 2. The third group of 20 words was comprised of words having 100% consensus with ratings 1,

2 and 3 combined or with ratings 2 and 3 combined. Consensus was not obtained on low ratings.

The 140 words were shown to a sign language interpreter in a school for the deaf, who was asked to select those that were most probably understood by deaf students and could be expressed as single sign-lexicons or in other forms of sign expression. Altogether 91 words were selected. The paired associate learning tasks were constructed with 40 of the 91 words, and the free-recall task was constructed with 16 of the 91 words. After a pilot study with three deaf students, the number of words to be used in the main study was finally determined. As fatique and proactive interference were observed in the pilot testing procedure, the number of test words was decreased to a total of 36. Thirty-three words were from the group with 100% consensus on rating 1 or ratings 1 and 2 combined; the remaining three words were words which had 100% consensus with ratings 1, 2 and 3 combined. Thus the final word stimuli were either extremely high or high in imagery value. The choice of the words was also governed by the possibility of forming categories for the free-recall task, and associations varying in typicality for the paired-associate learning tasks.

Method

Sample Selection

Permission to conduct research in two Western Canadian schools of the deaf was obtained. Two other Western Canadian schools of the deaf were also contacted, one of which was currently involved

in another large-scale research project, and therefore the students could not participate in the present research. Six hearing-impaired students who attended the other school part-time were willing to participate. All these students were over 20 years old and would not be available for testing until a later time in 1988. Therefore, the sample of subjects was selected from only the first two schools of the deaf.

After the initial screening according to the reading vocabulary results of the Canadian Achievement Tests in one school. Thirty-three potential subjects were identified and thirty-three letters to the parents and consent forms were sent out through the school administration. Nine of the forms were returned to the school which were subsequently returned to the researcher. Three parents did not return the form but gave verbal consent to the school administration, and their consent was communicated to the researcher. Due to the low response rate, the school administration approved of the researcher's request to provide the telephone numbers of the remaining parents or guardians. The parents or guardians were subsequently contacted, except a few cases with no telephone number or wrong number. The reasons for failing to return the forms were either due to misplacement, not having received the form or the decision was left to the students concerned. A number of parents/guardians gave consent on the phone. As for the older students whose parents/guardians left the decision to the students, consent was solicited through the school administration. After this process, thirteen more subjects were selected.

Due to the distance of the second participant school, communication with the school administration was conducted by means of mail correspondence and telephone communication. The school administration was requested to initially select potential subjects according to the same specified criteria as in the first school. Thirty letters to parents and parental consent forms were mailed to the school to be sent out to the parents or guardians. However, the school administration informed all parents/guardians of this request for subjects. Together with the school newsletter, all parents/guardians were sent a copy of the letter and consent form. The returned forms were later collected from the school by the researcher in person. Nine forms were returned and two parents gave verbal consent. Upon inspection of the school records of the eleven students, one student was excluded because he had another disability and was older than the upper bound of the targeted age range. The remaining ten students were scheduled for testing on later dates. When the researcher returned to the school for data collection, one of the ten students was absent from school due to illness.

Altogether thirty-four deaf students participated in the research. Three of them were subjects in the piloting procedure. The rest served as subjects in the main study. Thirty-one subjects were tested, but 24 of them were included in the final analysis. The exclusion of seven subjects was either due to indications of high distractability, low motivation, communication problems even with sign interpretation or extremely low semantic knowledge.

The 24 subjects were 12 male and 12 female deaf students attending either one of the two schools of the deaf, between the ages of 9 and 20.42 years. The mean age of the sample was 15.36 years. All subjects had bilateral sensory-neural hearing loss, ranging from severe to profound in the better ear. Specifically, four subjects had a severe hearing loss ranging from 78 to 90 decibels; three had a profound loss which exceeded the measurement threshold of the audiometer; the remaining subjects had a profound loss ranging from 92 to 113 decibels.

With respect to the age of onset of deafness, 14 had deafness diagnosed at birth, 7 had their hearing loss diagnosed in early and late infancy, three had unknown age of onset and etiologies. Of the 14 congenital cases, six were hereditary, two were because of maternal rubella, one was due to premature birth, and five had unknown causes. Of the seven cases with hearing loss diagnosed in infancy, four had unknown causes, one was due to menigitis, one was due to maternal rubella, and one was due to high fever. Apart from hearing loss, the subjects were without other known disabilities.

Thus, 58.3% of the sample was classified as having congenital deafness, which moderately exceeded the 1 to 1 ratio of congenital versus postnatal prevalence, as the prevalence of the former is 1 per 1000, and prevalence of the two together is 2 per 1000 (Bamford & Saunders, 1985). Of the congenital cases, 25% was due to hereditary factors, and 12.5% was due to maternal rubella. This confirmed that hereditary cause is the most frequent cause

(Moores, 1978), and that the two most frequently known causes of congenital sensory-neural deafness are firstly genetic factors and secondly maternal rubella (Upfold & Isepy, 1982). The total percentage of cases with unknown causes of deafness in the sample was 50%. This fact also confirmed that a great proportion of cases of sensory-neural hearing loss is of unknown etiology (Moores, 1978; Taylor, 1980; Martin, 1982).

The subjects were screened either according to the reading vocabulary test results of the Canadian Achievement Tests in one school or according to results on language arts in the school report in the other, since the second school did not have systematic standardized evaluation. Grade 3 reading level was used as the criterion, since the median reading age of 15- to 16-year-old deaf children was found to be equivalent to a hearing 9-year-old (Conrad, 1979). Subjects selected either had attained a grade level of 3 or above on the reading vocabulary of CAT, or a grade of B or above on language arts. All subjects were finally selected based on the pre-test word review, with the cut-off point at 80%.

Test Instruments and Procedures

(1) Metamemory Interview

Four subtests: story list, study plan, retrieval event, and opposites-arbitrary were selected from the Kreutzer et al.'s (1975) interview. The wording of retrieval event was slightly modified. Changes were made to story list, study plan and opposites-arbitrary. A scoring criterion was also developed. Before the interview, the

subjects were told that they would be asked some questions about memory, and that sometimes pictures were used.

(a) Story list: This subtest explored the awareness of why the elaborative relationship among items could facilitate recall. Seven pictures of colored drawings were used. Each item was drawn on a 12.8 cm by 7.6 cm white card. In the original procedure of Kreutzer et al. (1975), half of the subjects had the list presentation first, the story presentation second, and the other half in reverse order. In the present procedure, the same order was used for all. The seven pictures were presented consecutively showing colored drawings of "bed, tie, shoes, table, dog, hat and car". The subject was asked to look at the pictures. At the second presentation, the following description, which was slightly different from the original, was given. The corresponding picture was shown when it was named.

"I showed these pictures to two children, Tom and Mary. When I showed Tom the pictures, I simply asked him to learn them so that he could tell me what they are later, when I took the pictures away. When I showed Mary the pictures, I also told her a story about the pictures. The story went like this: A man gets up out bed and gets dressed, putting on his best tie and shoes. Then he sits down at the table for breakfast. After breakfast, he takes his dog out for a walk. Then he puts on his hat, gets into his car and drives to work. I told Mary that she had to learn the pictures but not the story, so that she could tell me what the pictures are later, when I took them away."

Then three questions were asked.

Q.1. Do you think the story makes it easier or harder to remember the pictures?

Q.2. Who do you think learned the most, remembered more pictures, Tom or Mary?

Q.3. Why do you think (Tom/Mary) learned the most?

(b) Study plan: This subtest was designed to determine the knowledge of the most suitable organizational strategy for the task, i.e., taxonomic categorization, and the knowledge of different strategy use of a person with less advanced abilities. Nine pictures of three categories were shown. The pictures were colored drawings on the same kind of card used in the first subtest. The items were hand, foot, lemon pie, hot dog, red apple, blue jacket, orange sock and red cap. The body group, food group and clothing group were presented and laid out on the table in three rows. One picture was presented at a time. The order of the groups varied across subjects, each group was presented as the first, second or last row the same number of times. In the original form, the items were presented in random order. Then the following was said to the subject:

"Suppose I gave you these nine pictures to learn. You don't have to learn them now, just suppose. And I gave you three minutes to learn. You could do anything you wanted with the pictures. You might want to move them around to help yourself to learn them. Later, when I took away the pictures, you had to tell me what they are."

Two questions were asked.

Q.1. What would you do to learn these pictures so that you can remember them very well?

Q.2. Suppose I gave the pictures to a 4-year-old and asked him to learn them and gave him three minutes. How would a 4-year-old child learn these pictures? What would he do with the pictures to help himself to learn them?

In the original form of the interview, three more questions were asked: Do you always learn things this way? Did anyone ever tell you to learn this way? If you were small, how would you have learned these pictures. In the piloting, it was found that these questions caused misunderstanding from the deaf subjects, and therefore they were eliminated. Also the age of the young child was unspecified in the original Kreutzer et al.'s (1975) interview.

(c) Retrieval event: This was a test of knowledge of search strategies and the levels between external mediation and internal mediation. Internal mediation would be characterized by the use of greater planfulness and elaboration; according to Kreutzer et al. (1975), this should emerge at the end of middle childhood.

The following was said to the subject.

"Suppose you had a friend, and he had a dog. Suppose you wanted to know how old the dog was. Your friend told you that it was born one Christmas, but he could not remember which Christmas it was."

Two questions were asked.

Q.1. What things could he do to help himself to remember which Christmas it was?

Q.2. Is there anything else you can think of?

(d) Opposites-arbitrary: This was a test of the awareness of the characteristics of content material which could be helpful or non-helpful cues to memory. The recall element in the original format was eliminated, because a paired-associate learning task had also been used in the test battery. Word pairs of two types written on small cards were shown to the subject. The opposites list consisted of three pairs intead of four as in the original version. These were hard-easy, cry-laugh and black-white. The name-plus-action list consisted of four items as in the original form. They were Ann-sit, Mary-walk, Joe-climb and Charlie-jump. The order of list presentation was counterbalanced. The cards were laid out in two rows corresponding to the groups.

The following was said:

"Suppose I gave you these word pairs to learn. You don't have to learn them now. We have just done a similar thing; just now I gave you one word of the pair and you gave me the other. Now look at these pairs; some are made of opposites, some are made up with a name and an action."

Three questions were asked.

Q.1. Which kind of word pairs is easier to remember, the opposites or the name plus action?

Q.2. Why is (opposites/the name plus action) easier than the other one?

Q.3. If I gave you six easier pairs (like six opposites/the name plus action, according to the subject's answer in the previous

question) and five harder pairs like those (the name plus action/opposites), could you remember the six easier pairs better than the five harder pairs?

The target of the questions differed from that of the original interview. In the original Kreutzer et al.'s (1975) form, the experimenter progressively added blank cards to the preferred category of the subject until the child judged the originally nonpreferred set to be easier to remember. The present form was intended to measure the judgment of quality only, and the consistency of the judgment under slight variation of quantity, since it was hard to verify how many more items would be critical to reverse the decision.

(2) Spatial Position Versus Temporal Postion Test

The stimuli were three lists of three letters of the alphabet in each, and three lists of three arabic numbers in each. The letters in upper case and numbers were each printed in black, 5.5 cm high, on a 12.8 cm by 7.6 cm white card. The letters were chosen and combined on the basis that the equivalent handshapes in American sign alphabet do not involve direction of movement in the formational properties, and visually in orthography they are distinct from each other. The numbers were randomly combined to form groups of three. The lists were: G Y W, F S N, K L D, 7 2 4, 9 5 3 and 1 8 6. The letters A E U were used in practice trials; A and E were confounding handshapes. The letters H J R were used in the instruction procedure. The order of the type of lists was counterbalanced across subjects, so that half received the letters first, and half received

the numbers first. The order of lists within type was randomized. In the presentation, three cards were placed face down in a straight row behind a paper screen. When the screen was removed, each card was exposed for one second, one after another, and put back to the original face down position. The temporal order of exposure did not occur from left to right or right to left in all trials. The four sequences of the three spatial positions were: [Middle, left, right], [middle, right, left], [left, right, middle] and [right, left, middle]. The second one in the sequence never corresponded to the spatial middle position. Altogether there were eight trials, twice for each sequence, with one alphabet list and one number list used twice in the trials. The subject was given the following instruction and three cards each with H, J, and R were used in the demonstration.

"We are going to play a memory game with some numbers and English letters. The numbers and letters are written on small cards, one number on one card, and one letter on one card.

First I will place three cards face down behind a screen. The three cards form a row, one to the left, one in the middle, one to the right. Later, I will turn the cards over quickly and put them back again. I will turn one card over, put it back, then I will turn another one over, put it back, and lastly I will turn over the third card and put it back.

Then I will ask you two different kinds of questions. I will ask you 'What is the middle one of the row?', or I will ask you 'What is the middle one I showed you?' The middle one of the row is the card's place on the table, it is not the left one, and not the

right one. When I ask for the middle one I showed you, you have to tell me the second card I turned over, because I turned over the cards one after another, first, middle, third. The second one was the middle one I showed you according to the order."

Unlike the experiment of O'Connor and Hermelin (1972), the concept of middle was explained. It was suspected to have caused confusion to deaf individuals in O'Connor and Hermelin's (1972) experiment. Due to different linguistic convention, the term "middle" in sign language only refers to spatial position, while for temporal sequence, ordinals are used. When the subjects indicated dissatisfaction with the usage of "middle" in the instructions, they were told that it was deliberately done in this task and they had to be very attentive to the different questions. Also, the sign language interpreter was asked in advance to make the differentiation in the interpretation of the questions without using the ordinal second. It was ensured that the subjects understood the requirements of the task by giving them practice trials.

One spatial practice trial and two temporal practice trials were given, using the letters A, E, U, and arranging them according to the [right, left, middle], [middle, right, left] and [middle, left, right] sequences. When the subject failed all test trials, explanation was given briefly again, and the first temporal practice trial was administered again. If the subject still failed, the second temporal practice trial was administered again.

(3) Word Review

The pre-test word review served as an index of the semantic knowledge of the subjects. The 36 words which were used again in the free-recall and paired-associate learning tasks were each printed in black on 12.8 cm by 7.6 cm white cards. The subject was shown one card at a time in the beginning of the test session. To make sure the subject had already known the word, he/she was asked to give the sign equivalent. Finger-spelling was accepted if the subject could give the definition. If a word was not familiar, the explanation was given; if a word had several possible meanings and the non-targeted meaning was given by the subject, the other meaning was also explained. The sign equivalents for the corrections were given by the interpreter. The following instruction was given:

"Since we are using many English words, I want to see whether you can sign all these words. I will show you very quickly one word at a time on a piece of card, and you sign it, the interpreter will say it in speech. If you don't know a word, tell me, and the interpreter will sign the word for you."

(4) Paired-Associate Learning

The paired associate task explored the possible use of elaboration in varying task conditions. The conditions were determined by the degree of prototypicality inherent in the relationship between the two words. Ten word pairs were printed on a white card 28 cm by 21.5 cm in one column. The pairs were made up of five prototypic and five non-prototypic pairs which were in random order. The formation of word pairs was based on the meaning and

references given in Gage's Dictionary of Canadian English: The Beginning Dictionary (Avis, Gregg, Lovell, & Scaargill, 1962), and Webster's New World Dictionary: Elementary Edition (Guralaik, 1966). Prototypicality was based on whether direct mention or indirect references to one word of the pair exists in the dictionary definition of the other word. Prototypicality was also based on the common associations of concepts when the above principle was not fulfilled. For example, "farmer-harvest" was judged to be prototypic and familiar since farming is a common activity in the provinces where the research was done. The non-prototypic pairs were constructed based on possible meaningful relationships, according to the judgment of the researcher. Five of the cues were words on the left hand side, and five were words on the right hand side. Each cue word was printed on a 12.8 cm by 7.6 cm white card, and was exposed for one second. The order of the cue words was randomized across subjects, except the pair sunset-evening which was counterbalanced as either the last test item, or the second last test item. After the recall, the subject was asked to draw a picture and write a sentence describing how the pairs went together for each of the last two recalled items. Instruction was given and the possible ways to elaborate on a paired-associate were prompted. Examples were used in the instruction. Three word pairs not included in the test stimuli were printed on a small white card in one column. A sentence and a drawing describing each of two pairs were printed on a small white card. Each of the two example cues were printed on a small white card. A two minute study period was given to the subject. The

exposure time of the cue was one second, the maximum cue-recall interval was approximately three seconds. The instruction was as follows:

"You will have some word-pairs to learn. A word pair is made up of two words, e.g., I put 'cat and bird' together, 'road and bus' together, 'box and rock' together in this short list.

You will have ten word pairs to learn, they are printed in one column. When you learn the words, think of the meaning, how they can go together. Think of a picture with the two words. For example, for the pair 'cat-bird', I can think of a picture and a sentence, 'The cat tries to catch the bird.' For 'box-rock', I can think of a picture and a sentence, 'Someone put a rock into the box.'

You have two minutes to learn this list. Then I will show you a card with one word of a pair. You have to answer in sign language the other word of the pair. For example, for this short list, when I give you 'cat', you have to answer 'bird'. When I give you 'rock', you have to say 'box'."

(5) Free-Recall

The free-recall task was designed with categorizable items from four categories, which were people, places, fruit and body parts. The aim was to assess the use of clustering strategy in contrast to seriation strategy, since both strategies were said to be used frequently in free-recall (Mandler, 1969). Contrary to Postman (1972) who regarded both strategies as equally efficient in list learning, it was suggested here that clustering would produce better performance. The stimuli were four categories of four items each.

Seven lists were made with one item of each category adjacent to each other, and no two items of the same category were adjacent to each other. The order of the categories within every four items was randomized. The 16 words were printed in one single column in the middle of a 28 cm by 21.5 cm white card. The lists were randomly assigned to the subjects. The class structure of the list was hinted and the subjects were instructed that the order of recall was not important. Three minutes of study time were given and one minute thirty seconds were allowed for immediate recall. The following instruction was given:

"You will have a list of 16 words to learn. These words are from four classes. For example, table, chair can go together to make a class. Cat and dog can go together to make another class. The 16 words are written in one column and you have three minutes to learn them and remember them. Then you have to tell me the 16 words in sign language. You don't need to follow the order of the list when you tell me the words. There are four classes of words, but now I am not telling you what the classes are. You have to learn as quickly as you can."

(6) Digit Span

The digit span forward test was taken from Wechsler Intelligence Scale for Children-Revised (WISC-R) (Wechsler, 1974). The purpose for its use in this research was to give an index of capacity of working memory. The procedure was different in that the interpreter interpreted each spoken digit for the deaf subjects. Therefore the manual code was used in a sequence. Both trials of the

scale were used. Two practice trials each with two numbers (5 4, 3 1) were given. The instruction to the subject was:

"I am going to say some numbers, several at a time. When I say a number, the interpreter will sign the number. When we are through, you have to give all the numbers in order. I will indicate it is your turn."

(7) Color Sequence Matching

This was an interpolated task between tests as well as an informal enacted context for behavioral observation of sequential or nonsequential strategies. Five colors, red, blue, green, yellow and purple, were used to draw a set of circles and a set of triangles on small white cards. The five cards with triangles were given to the subject and the researcher used the other set of circles. A sequence of colors was shown and each card was put back to the fanshape pack held in the other hand after an approximate exposure of one second. The subject was encouraged to follow the sequence as well as the colors. Two colors were used in the two demonstration trials; four trials of three colors and four trials of four colors were used in between the main tasks.

The following was said as introduction to the task:

"We are going to play a color matching game. I have two piles of cards, one pile has all circles, one has triangles. They are all drawn in five colors, red, blue, green, yellow, purple. Later you keep the triangles, I keep the circles. When I show you several colors, you have to show me the same colors very quickly. For example, when I show you red, green you have to show me red,

green. When I show you blue, yellow, you have to show me blue, yellow. Let us practise the colour matching game. You hold the five cards like a fan in one hand or whatever way you like."

General Testing Procedures

Data collection was conducted in October, November and December of 1987. Each subject was tested individually according to a prearranged schedule. A sign language interpreter was present during every session. Three sign language interpreters were involved, with one interpreting most of the sessions, two of whom were school interpreters. Interpretation was not carried out as word for word transliteration. The main purpose of interpretation was to convey the instruction. Therefore, the interpreters were given the freedom to adjust to the students' communication mode. However, the interpreters were required to interpret in specific ways for the spatial position versus temporal position test and digit span. For the former, the interpeters were cautioned in advance not to give away clues in interpreting the spatial and temporal "middle" questions. For the latter, the interpreter shadowed each spoken digit and the pause after each digit. The duration of the test sessions varied between one hour to one hour 15 minutes. Audio cassette tapes and a tape recorder were used to record the interpretation in speech; a stop watch was also used for timing. The subject always sat facing the researcher and the interpreter across the table, and the interpreter was always seated to the right side of the researcher. In both schools, the testing was conducted in a

small room. At the beginning of each session, the researcher introduced herself and explained that the purpose of the testing was for research and it was not used for grading purposes. Also the use of the tape recorder was explained and the subject was asked to use sign language or sign language together with speech in communication. Then the test materials that were to be used were briefly introduced. In the testing procedure, the word review always came first, followed by introduction to color sequence matching and digit span; the spatial position versus temporal position test was the fifth and the metamemory interview came last in the testing procedure. The order of paired-associate learning and free-recall was counterbalanced as the fourth or the sixth test. At the end of the testing session, each subject was presented a thank-you letter with a specially designed souvenir.

Data Analysis Procedures

Metamemory Scoring Procedure

The metamemory interview was transcribed from the audio-cassette tape onto which the English interpretation of the interpreters had been recorded. The interview protocols of the first half of the sample were independently scored by the researcher and two other graduate students. The two other scorers were paid and each was individually trained on the scoring criteria. The classification of the types of response was based partially on the study of Kreutzer et al. (1975). However, the scoring system was

uniquely devised for the present research, since no scoring system was developed by Kreutzer et al. (1975). (See Appendix 1.)

The scoring system consisted of assigning scores to answers in three subtests, namely story list, retrieval event and opposites-arbitrary. Answers to study plan were classified according to seven possible types of response. Ranging from high to low level response, the seven types were complete categorization, association, partial association, rehearsal, passivity, random rearrangement and nonresponse. The raters were required to score according to the criteria for the subtest questions and identify the types of response for questions 1 and 2 of study plan. Subsequently the types of response of study plan were given scores by the researcher. Scores to retrieval event were given according to six response types. These were self-indirect-elaboration, self-direct-elaboration, plausible note, others, plausible note, impossible note and nonresponse. Also scores were given with respect to four categories of response for question 2 of opposites-arbitrary.

The inter-rater reliability for the metamemory interview was calculated as the percentage of agreement among the two raters and the researcher for the first half of the sample, and between the two rating trials of the researcher for the second half of the sample. The inter-rater reliability was 86.66% for all the metamemory subtests. The inter-rater reliability for story list was 88.88%, for retrieval event was 87.5%, for opposites-arbitrary was 91.66%, and for study plan was 79.17%. Having obtained a high inter-rater reliability, the scoring system was proven to be reliable

and the second half of the sample was scored by the researcher. The intra-rater reliability was 97.50%.

Analysis of Strategy Use in Free-Recall

The method to detect organizational strategy use from the recall response was based on the formula of Mood (1940), Wallis and Roberts (1957), and the research of Cole, Frankel and Sharp (1971). The measurement of taxonomic clustering in free recall response usually used by reseachers was said to be subject to the problem of neglecting the different number of items recalled (Cole et al., 1971). The formula derived from Mood (1940) corrects this difficulty, which calculates the mean and variance of the number of items from within each category for each recall list.

As given by Wallis (1957, p.571), the mean number of runs of elements of k types is given by

$$M_r = \frac{n(n+1) - \xi n_k^2}{n}$$

and the standard deviation σ_r is given

$$\sigma_r = \sqrt{\frac{\xi n_k^2 \left[\xi n_k^2 + n(n+1)\right] - 2n\xi n_k^3 - n^3}{n^2(n-1)}}$$

where n = total number of elements and n_k = number of elements of the k class.

Cole et al. (1971) used this information for the calculation of a z score which indicates tendencies towards clustering.

$$z = O - M \; / \; \sigma_r$$

where O = observed number of runs.

The sign of the z score is changed so that positive z scores indicate clustering.

The calculation of serial order strategy in free recall output was based on the suggestion of Cole et al. (1971). Serial position alone is insufficent to assess the strategy of using serial order. The measure proposed by Cole et al. (1971) consists in assigning each recalled item a number corresponding to that same item's position on the input list, and then calculating a Pearson correlation coefficient between the input and output positions. Serial ordering will be indicated by positive correlation.

These two methods described above were used in the analysis of the present study. A clustering score and a seriation score were calculated for the free-recall output in the sample.

Statistical Analysis for Hypothesis Testing

The statistics used in the analysis were mainly for the measurement of "profile", and to a less extent, for the measurement of "elevation", with the use of correlation coefficients for the former and t-tests for mean comparisons for the latter (Kerlinger, 1973). The test data were examined based on a minimum 1-tailed probability of 5 per cent. Pearson correlation coefficient, chi square test of independence (Yates' correction for continuity) and contingency analysis were used for testing hypothesis 1 to 5. T-test for correlated samples was used for testing hypothesis 6.

Descriptive statistics were also used in the analysis of the variables.

Calculation of Reliability

Reliability was calculated for the various tests. The Cronbach alpha coefficient was used for the metamemory subtests and digit span. The Spearman-Brown formula for split-half reliability was used for the items in the two paired-associate conditions, the two types of stimuli used in both the spatial position and temporal postion, and the items of free-recall.

CHAPTER IV

RESULTS

Introduction

This chapter will present the research findings. First, general findings and results pertaining to the hypotheses will be reported. The next section consists of informal behavioral observation. Lastly, the measurement of reliability will be reported.

Results Pertaining to Hypotheses

The general profile of performance was indicated by a negative skewness, except on the digit-span test which showed a positive skewness. (See Table 1.) The Pearson correlation coefficients of the test measures are shown in Table 2.

Significant positive correlations were found among three metamemory subtests: between story list and study plan, and $r = .461$ ($p < .02$); between story list and retrieval event, $r = .726$ ($p < .001$); and between study plan and retrieval event, $r = .571$ ($p = .002$). Inter-subtest correlation was highest between retrieval event and story list, indicating more internal consistency between these two subtests. A metamemory composite score was obtained by summing the scores of the subtests. The subtest correlations with the composite score ranged from moderate to high: $r = .439$ ($p < .02$) for opposites-arbitrary; $r = .775$ ($p < .001$) for story list; $r = .786$ (p

< .001) for study plan; and r = .891 (p < .001) for retrieval event. The best indicator of metamemory seemed to be retrieval event followed by study plan and then story list.

TABLE 1

Mean, Standard Deviation, Skewness and Range of Scores

	Mean	Std. Dev.	Skewness	S.E. Skew	Min.	Max.
Story L.	2.333	.816	-1.239	.472	0	3
Study P.	7.333	2.120	-.180	.472	3	10
Ret. E.	6.333	2.884	-.435	.472	0	10
Opp. A.	3.750	1.539	-1.180	.472	0	5
Spat. P.	3.208	.833	-.918	.472	1	4
Temp. P.	3.083	1.100	-1.246	.472	0	4
Word R.	33.958	1.805	-.706	.472	30	36
Free R.	10.917	2.873	-.281	.472	5	16
Digit S.	4.250	1.189	.657	.472	3	7
P-A. P.	4.833	.482	-3.036	.472	3	5
P-A. N.	4.417	.776	-.918	.472	3	5

N. of Subjects = 24 Mean Age = 15.363 yrs.

TABLE 2
Pearson Correlations between Measurements and Age

	Age	Meta. C.	Story L.	Study P.	Ret. E.
Meta. C.	.508**				
Story L.	.545**	.775***			
Study P.	.339	.786***	.461*		
Ret. E.	.437*	.891***	.726***	.571**	
Opp. A.	.304	.439*	.242	.133	.166
Spat. P.	-.075	-.211	-.170	.189	-.356*
Temp. P.	-.254	.088	-.032	.174	-.078
Word R.	.391*	.619***	.659***	.447*	.520**
Free R.	.185	.297	.179	.140	.224
Cluster	.201	.396*	.252	.299	.282
Seriat.	.040	-.161	-.091	-.359*	-.002
Digit S.	-.257	.159	-.045	.104	.101
P-A. P.	.216	.192	.147	.227	.073
P-A. N.	.026	.065	-.023	.150	.065

	Opp. A.	Spat. P.	Temp. P.	Word R.	Free. R.
Spat. P.	.246				
Temp. P.	.193	.123			
Word R.	.262	.064	.133		
Free R.	.349*	.226	.250	.477**	
Cluster	.342	.045	.208	.515**	.902***
Seriat.	-.037	.240	-.041	-.406*	.008
Digit S.	.273	.033	.482**	.147	.261
P-A. P.	.176	-.018	.274	.342	.084
P-A. N.	.164	.264	.467*	.261	.348*

	Cluster	Seriat.	Digit S.	P-A. P.
Seriat.	-.164			
Digit S.	.320	-.237		
P-A. P.	.183	.107	.228	
P-A. N.	.220	-.166	.542**	.310

*** p < or = .001
** p < or = .01
* p < or = .05

Hypothesis 1. Memory and Metamemory

Hypothesis 1.1., which posited that a positive correlation between metamemory and memory performance, was not totally supported. Only word review was significantly correlated with three of the metamemory subtests. The Pearson correlation coefficient between word review and story list was .659 ($p < .001$), between word review and study plan .447 ($p < .02$), between word review and retrieval event was .520 ($p < .005$), and between word review and the metamemory composite score was .619 ($p < .001$). Among the subtests, story list was the best predictor for word review. Free-recall was found to be significantly correlated with opposites-arbitrary ($r = .349$; $p < .05$). Spatial position recall was negatively but significantly correlated with retrieval event ($r = -.356$; $p < .05$). These two significant correlations lent some more support to the existence of a relationship between metamemory and memory performance, although the second correlation requires a more complex interpretation in the next chapter.

As mentioned in the last chapter, the two organizational strategies, taxonomic clustering and seriation, were computed. In hypothesis 1.2, it was stated that metamemory would correlate positively and significantly with strategy use. Clustering was found to be significantly correlated with the metamemory composite score ($r = .396$; $p < .03$), and also marginally significantly correlated with opposites-arbitrary ($r = .342$; $p = .051$). Seriation was negatively and significantly correlated with study plan ($r = -.359$; $p = < .05$). However, clustering was not significantly correlated with study plan.

This will be discussed in relation to age. In sum, the results offered a weak support of hypothesis 1.2.

Hypothesis 2. Strategy and Recall

Hypothesis 2.1., which predicted better recall performance was correlated with appropriate strategy use, was supported; clustering was highly correlated with free-recall performance, with $r = .902$ ($p < .001$). The relationship between seriation and free-recall performance was nearly zero ($r = .008$). Also, though not reaching significant level, clustering was correlated with digit span ($r = .320$; $p = .064$).

Hypothesis 3. Between Memory Tasks

Hypothesis 3.1, which predicted word review to be positively correlated with free-recall and paired associate learning, was partly supported. Word review was found to be correlated with free-recall, as well as clustering, with $r = .477$ ($p < .01$) and $r = .515$ ($p = .005$) respectively, and with seriation ($r = -.406$; $p < .03$). The correlation between word review and prototypic paired-associate condition was marginally significant ($r = .342$; $p = .051$). Thus, the hypothesis of the existence of significant positive correlation between word review and the two word related memory tests was given some support. Although the correlation between the non-prototypic paired-associate condition and free-recall still had to be explained, it reached significance level with $r = .348$ ($p < .05$). Correlation between digit span and temporal position recall was significant, with $r = .482$ ($p < .02$), thus supporting hypothesis

3.2 which proposed a significant positive correlation between the two measurements.

Hypothesis 4. Age and Metamemory

The degree of hearing loss was not correlated with any of the measurements, whereas a developmental trend was observed with metamemory performance, but not with memory performance or strategy use. Hypothesis 4.1 which stated that age increase correlates positively and significantly with metamemory performance was supported with some qualification. Age correlated significantly with two subtests, story list ($r = .545$; $p = .003$) and retrieval event ($r = .437$; $p < .02$), and with the composite score ($r = .508$; $p < .006$). The correlation of study plan with age was marginally significant with $r = .339$ ($p < .053$), but age was found to be not significantly correlated with opposites-arbitrary.

The age factor was analyzed in another manner, since hypothesis 4.1 concerning age and metamemory was only partially supported. Contingency analysis was applied to the opposites-arbitrary subtest. One possibility for the lack of an age trend was because the majority of the sample was made up of adolescents and late adolescents, and a plateau of performance might have been reached in late childhood. In order to discriminate the differences between the pre-adolescent, adolescent and late adolescent to young adult groups, the sample was divided into three groups: 9 to 13 years, 13.1 to 17 years, and 17.1 to 20.4 years. The groups were compared in 2 x 2 tables, with age relative to scores

above or below the mean; χ^2 was not significant in all comparisons. (See Table 3.)

TABLE 3

Contingency Table on Opposites-Arbitrary across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	2 (40%)	11 (84.62%)	5 (83.34%)
Below Mean	3 (60%)	2 (15.38%)	1 (16.66%)

The scores of study plan were further analyzed likewise in three age groups. Most of the subjects 13 years and below had less than average performance, and most subjects who were above 17 years old showed above average performance. The middle age group seemed to be at a transitory stage, with seven (53.85%) of them showing below average performance. The groups were compared in 2 x 2 contingency tables; χ^2 was not significant in all comparisons. (See Table 4.)

TABLE 4

Contingency Table on Study Plan across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	1 (20%)	6 (47.15%)	4 (66.67%)
Below Mean	4 (80%)	7 (53.85%)	2 (33.33%)

Although a significant correlation was found between the subtest retrieval event and age, it was of moderate level. Contingency tables of both retrieval event and story list were compared. It was found that on retrieval event, there was little difference in the percentage of individuals scoring above the mean between the middle age group (eight subjects, i.e., 61.54%) and the oldest age group (four subjects, i.e., 66.67%). This therefore explained the less distinct age trend, whereas for story list, the difference in the percentage of subjects who showed above average performance was greater between the middle age group (seven subjects, i.e., 53.85%) and the oldest age group (four subjects, i.e., 66.66%). The percentage of oldest subjects who scored above average on both subtests remained the same. (See Tables 5 and 6.)

TABLE 5

Contingency Table on Retrieval Event across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	0 (0%)	8 (61.54%)	4 (66.67%)
Below Mean	5 (100%)	5 (38.46%)	2 (33.33%)

TABLE 6

Contingency Table on Story List across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	1 (20%)	7 (53.85%)	4 (66.67%)
Below Mean	4 (80%)	6 (47.15%)	2 (33.33%)

In general, the choice of strategies on both retrieval event and study plan indicated that higher order strategies were selected by at least half of the subjects. Fourteen subjects suggested categorization on study plan; six suggested association. On retrieval event, 11 subjects suggested self-indirect elaboration, while one suggested self-direct elaboration on the first trial. However, over 40% were dependent on external and social retrieval cues. (See Tables 7 and 8.)

TABLE 7

Frequency of Strategies of Study Plan *

	Self-choice		Attribution	
	N.	%	N.	%
Complete Categorization	14	58.33	5	20.83
Association	6	25	1	4.17
Partial Association	3	12.50	1	4.17
Rehearsal	1	4.17	0	0
Passivity	0	0	8	33.33
Random Rearrangement	0	0	4	16.67
Non Response	0	0	5	20.83
Total:	24	100	24	100

* See Appendix 1 for strategy definitions.

TABLE 8

Frequency of Strategies of Retrieval Event *

	Trial 1		Trial 2	
	N.	%	N.	%
Self-indirect elab.	11	45.83	8	33.33
Self-direct elab.	1	4.17	1	4.17
Plausible note	5	20.83	5	20.83
Others	5	20.83	4	16.67
Impossible note	1	4.17	0	0
Non Response	1	4.17	6	25
Total:	24	100	24	100

* See Appendix 1 for strategy definitions.

Hypothesis 5. Age and Memory

Hypothesis 5.1 suggested that age increase correlates positively with memory performance and hypothesis 5.2 suggested that age correlates with better strategy use. With regard to the relationship between age and memory performance, the analysis showed that correlation between age and word review was significant, with $r = .391$ ($p < .03$). Still, it was weak support because correlations

with other memory tests were not significant. Contingency analysis was carried out with the two conditions of paired associate learning, the free-recall, the spatial versus temporal position encoding and the digit span test. (See Tables 9, 10, 11, 12 and 13.)

TABLE 9.

Contingency Table on Free-Recall Across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	1 (20%)	11 (84.62%)	2 (33.33%)
Below Mean	4 (80%)	2 (15.38%)	4 (66.67%)

Only the comparison between the youngest group and the middle group on the free recall test was significant, $\chi^2 = 4.189$ ($p < .05$; 1 df) indicating an association between age and performance. However, there were particular group characteristics with regard to the spatial position versus temporal position test. Of the oldest group, 83.33% performed below average on the temporal position test, while 50% of the same group had below average performance on the spatial

TABLE 10

(a) Contingency Table on Paired-Associate Learning Prototypic Condition across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	5 (100%)	10 (62.50%)	6 (100%)
Below Mean	0 (0%)	3 (37.50%)	0 (0%)

(b) Contingency Table on Paired-Associate Learning Non-Prototypic Condition across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	2 (40%)	8 (61.54%)	4 (66.67%)
Below Mean	3 (60%)	5 (38.46%)	2 (33.33%)

position test. The other two age groups' performance on the spatial position test was slightly worse than on the temporal position test. Of the 9 to 13 year old subjects, 40% were below average on the temporal position, and 60% were below average on the spatial position. Of the 13.1 to 17 years group, 46.15% were below average on the temporal position test, and 61.54% were below average on the spatial position test. (See Table 11a and b.) In terms of the types of errors, the highest number of temporal-to-spatial errors were made by the oldest group, and also half of the subjects in this group made this type of errors. In contrast, the greatest number of persons who made other random errors was from the middle group, and the greaatest number of such errors were made by this group. Across the three types of errors, the number of persons and number of errors from the youngest group remained constant. (See Table 12.) Both the youngest and the oldest groups seemed to have difficulty on the digit span test, with 83.33% of the oldest group showing below average performance and 80% of the youngest group showing a similar pattern. In contrast, only 46.15% of the middle group showed below average performance. (See Table 13.) The oldest group exhibited the highest percentage of below average performance on both the temporal position and span test.

TABLE 11

(a) Contingency Table on Spatial Position Recall across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21yrs.
Above Mean	2 (40%)	5 (38.46%)	3 (50%)
Below Mean	3 (60%)	8 (61.54%)	3 (50%)

(b) Contingency Table on Temporal Position Recall across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	3 (60%)	7 (53.85%)	1 (16.66%)
Below Mean	2 (40%)	6 (46.15%)	5 (83.34%)

TABLE 12

Error Patterns of Spatial Position vesus Temporal Position Test across Age Groups

		Age Groups in Years		
		9 - 13	13.1 - 17	17.1 - 21
Temporal-	N. Subjects.	2	4	3
to-Spatial	N. Errors.	2	4	7
Spatial-	N. Subjects	2	2	3
to-Temporal	N. Errors	2	3	4
Random	N. Subjects	2	8	4
	N. Errors	2	13	4

Total N. of Subjects = 24

N. in 9-13 years = 5

N. in 13.1-17 years =13

N. in 17.1-21 years = 6

TABLE 13

Contingency Table on Digit Span across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	1 (20%)	7 (53.85%)	1 (16.66%)
Below Mean	4 (80%)	6 (46.15%)	5 (83.34%)

Hypothesis 5.2 with regard to age and strategy use was examined with the use of contingency analysis, since the correlation between age and clustering was not significant. Although clustering has been reported of younger children when familiar material was used, the more reliable age for consistent clustering would be the end of elementary school years, as Ornstein, Naus and Liberty (1975) reported 13-year-olds rehearsed members of categories together. Therefore the subjects were divided into two groups, 13.1 years and above, and 13 years and below. The χ^2 of 3.267 failed to reach 5 percent significance level, but it was less than 10 percent. This non-association between age and clustering was attributed to a below average performance of eight subjects above age 13.

When the subjects were divided into three age groups as was done in the earlier analyses, it was found that four of the six

(66.67%) oldest subjects performed below average, while four of the thirteen (30.77%) adolescent subjects performed below average. (See Table 14.) The association between age and performance was significant when the youngest group was compared with the middle group ($\chi^2 = 4.43$, $p < .05$; 1 df); however, it was not significant when the comparison was made between the youngest and the oldest group, and between the middle and the oldest group. Of the six subjects who had significant seriation scores, five of them had below average clustering scores at the same time. Two of them were from the youngest group (40%), two were from the adolescent group (15.38%), and one was from the oldest group (16.66%). The relationship between age and appropriate strategy use was not shown to be a linear function, and therefore hypothesis 5.2 was only partially supported.

TABLE 14

Contingency Table on Clustering across Age Groups

	9 - 13 yrs.	13.1 - 17 yrs.	17.1 - 21 yrs.
Above Mean	0 (0%)	9 (69.23%)	2 (33.33%)
Below Mean	5 (100%)	4 (30.77%)	4 (66.67%)

Hypothesis 6. Task Conditions

With regard to intra-task variables, it was proposed in hypothesis 6.1 that spatial-to-temporal confusion would be significantly less than temporal-to-spatial confusion. Three types of errors were summed from the spatial position versus temporal position task. A spatial-to-temporal error was a temporal "middle" response given to a spatial "middle" question. Vice versa, a temporal-to-spatial error was a spatial "middle" response given to a temporal "middle" question. The third type of error was other random errors summed across the two kinds of questions. The mean number of spatial-to-temporal errors was less than the other two types. Paired t-tests were calculated, and the t-value was only significant for the comparison between spatial-to-temporal errors and other-random-errors ($t = -2.32$; $p < .03$, 1 tailed; $df = 23$). Thus, the hypothesis was not supported, as the level of significance was not reached in the comparison of the first two types of errors. Moreover, the performances on the two types of position recall were not significantly different from each other.

Comparison between mean difference of the two conditions of the paired-associate test yielded a significant result (t-value = 2.63; $p < .01$, 1 tailed; $df = 23$). Thus hypothesis 6.2 was supported, with the performance on the prototypic condition superior to that on the non-prototypic condition. The non-prototypic condition was also found to be positively correlated with temporal position ($r = .467$; $p < .02$) and digit span ($r = .542$; $p = .003$), both of which had not been predicted.

Observation Data

Color Sequence Matching Task

Color sequence matching was an interpolated task used for the purpose of diminishing possible proactive interference. It also served the purpose as an informal assessment of the use of sequential versus non-sequential strategies. With motor response indicators, the use of strategy was actually manifested behaviorally. There was more levity than a real experimental task, as the subjects were not compelled to follow the method used by the reseacher. Thirteen of the subjects, although reproducing correct sequences of colors, failed in doing so when four colors were used. Only one subject reproduced correct sequences for four colors; two subjects inconsistently reproduced such sequences. Of these fourteen sequence producers, three were from the youngest group, ten were from the adolescent group, and one was from the oldest group. Many subjects tended to ignore the repeated use of the same color in a sequence and showed the color only once. Eight of the subjects could be described as using some kind of spatial strategy. Two of them were preadolescent, three were adolescent and three were late adolescent subjects. Six of them spread the cards on the table. One subject used a strategy of elimination, by pushing away the corresponding stimuli not used by the experimenter. Three subjects always showed two cards simultaneously, one of whom had the cards on the table. One subject always used both hands for shifting the cards on the table.

Free-Recall and Paired-Associate Learning

Behavioral indication of monitoring, sensitivity to time allocation and also insensitivity to time allocation were observed in some subjects. A few subjects counted the number recalled in a category and stated the category name to check which other items were still omitted in the process of recall. In the study period, some subjects were observed to be memorizing to themselves; they studied for some time, looked away, and looked at the list again. In the paired-associate learning task, one subject was observed to cover one half of the pairs and then the other half as he studied. A few subjects who were sensitive to the time allocation controlled by the researcher would ask questions for clarification before the stop-watch was pressed. A number of subjects who were insensitive to the time allowed, asked questions in the middle of the study period. Also a few subjects were observed to put away the list prior to being told of the termination of the study period.

Post-Test Probe

An attempt was made to discover whether elaborative strategies were used for the paired-associate learning test by asking the subjects to draw pictures and write sentences of the last two recalled items. This did not seem successful, since all subjects took some time to think of what to draw and write, suggesting that the elaboration had not taken place earlier. Nevertheless, the products of this post-test exercise did show that the semantic relations expressed were highly similar across subjects. The

depiction of one pair which was requested of all subjects, i.e., sunset and evening was highly similar across subjects, with the exception of one. Even for the non-prototypic pairs which were recalled, the functional relations were expressed similarly in pictorial representation among subjects who had the same pairs, though not always so in the sentence form.

Communication Behavior

The communication behavior of the deaf subjects was noted. Part of the information was given by the interpreter. Six subjects used voice as well as manual communication. Two of these subjects ostensibly used speech in the rehearsal of digit span. In manual communication, there was a variety of individual differences. This was exhibited in the word review session, where different signs were used for some words; some subjects used more "colloquial" ASL signs, while others used signs which are used in the school. Some subjects were observed to use a sign for another related concept for a particular word, such as for "alcohol", the sign for "alcoholic anonymous" was used, yet the meaning of the word was correctly given. Some subjects preferred to finger-spell although they knew the meaning. Also, some of the signs used by the subjects and interpreters differed across the two provinces where the data were collected. Finally, in a few cases, some of the signs used by the deaf subjects were not immediately understood by the interpreters.

Measurement Reliability

The alpha coefficient for the four metamemory subtests was .647. Test-retest reliability was calculated for digit span based on the two trials, and the alpha coefficient was .590. The Spearman-Brown split-half method was used for the other tests. Items of the two paired-associate conditions were divided into odds and evens according to their consecutive order within item type on the test list. The reliability for the prototypic condition was not calculated because three of the five items had zero variance. The unequal length Spearman-Brown coefficient for the non-prototypic condition was .302, with three items in the first half and two in the second half.

For both spatial position recall and temporal position recall, the items were split into two halves of number stimuli versus letter stimuli. Therefore, the split-half reliability coefficient should not be taken in the usual sense. In this particular instance, the Spearman-Brown split-half formula was used to compare the two types of stimuli. The equal length Spearman-Brown coefficient was .065 for the spatial position, and .603 for the temporal position. For free-recall, each half was made up of two randomly selected items of each word category in corresponding category order, i.e., body, fruit, people, place; the equal length Spearman-Brown coefficient was .608.

In the next and final chapter, the interpretation of the results will be presented. Then some implications derived from the research will be given.

CHAPTER V

DISCUSSION AND CONCLUSION

Introduction and Goal

The last chapter presents the discussion of the results, drawing upon the conceptualizations of recent memory models and issues reviewed. Also, the results will be discussed with reference to the developmental phenomena commonly observed of the normally-hearing, and aspects specific to the deaf. Before the discussion, the goal of the study is restated, and the limitations are described. Then the discussion will be presented according to two broad topics: memory phenomena and metamemory. In the conclusion, issues and directions for future research will be addressed.

The goal of the study was to provide a better understanding of the interaction of the variables involved in the short-term and long-term memory of deaf students. These variables had been investigated with normal-hearing individuals in recent research of memory development. Specifically, in the present research, a profile description was attempted in regard to the interactions among metamemory, memory processes (representation and retrieval), strategy, knowledge, capacity, age and task characteristics.

Limitations

One limitation was the small number of test-items in the memory tests in particular with the paired associate conditions. The practical justification for not using longer tests was that the

testing procedure involving both an experimenter and interpreter was a laborious process. Longer tests would inevitably cause fatique which in turn would affect test results.

The small number of items might have influenced the overall picture of performance, which approached ceiling for nearly all items in the prototypic condition. The research interest, however, was not so much on performance as measured by absolute scores, but on the relationship between scoring profile and task characteristics, and scoring profile and strategy-use. Reliability was low for the paired-associate learning test and the spatial position test, possibly because of the limited number of items. Since the same kind of stimuli were used in the position encoding conditions, the difference in the split-half reliability would be indicative of some interaction between the task requirements and the items. The low reliability obtained in the spatial coding task suggested that digits and letters evoke different kinds of response patterns or processes. This seemed to relate to the suggestion of Das (1983) that digits and words are processed differently by the deaf. The design of the paired-associate learning conditions was actually for comparison with the free-recall task; the highly and fairly familiar structures in the paired associate-learning conditions therefore would not reflect differentiating level of difficulty.

It should be reiterated that the level of semantic knowledge required of the tests was deliberately adjusted to the level of semantic knowledge of the deaf subjects, and that spatial encoding had been repeatedly proven to be less difficult for deaf

individuals. The important point was the comparison of the performance on all the memory tests and on the conditions. It seemed that although the semantic stimuli and symbolic stimuli were of the same level, the variation of task nature produced different performance patterns.

Another limitation was the lack of test-retest reliability over a period of time. The interpretation of the results were therefore dependent on cross-references with other research studies in which similar constructs and instruments had been used.

The lack of an index of the intellectual functioning of the sample might be another limitation. Intelligence testing was not administered as part of the reseach procedure, for the reason mentioned above concerning the time involved in scheduling students. Standardized intelligence tests were not used in the schools, and therefore such an index was not available in school records. However, a global I.Q. measure does not provide a lot of information about the learning process, and the perspective adopted was on learning as an improvable activity. In fact, the present research would be a better candidate for the indication of intellectual functioning in terms of strategy and process. The word review, in a way was an index of the cognitive level of the subjects, as subjects were selected based on the 80% cut-off point. Just as the information subtest in the WISC-R (Wechsler, 1974) predicts general intelligence, the word review here could be regarded as serving a similar function as a predictor of knowledge level, with the loaded term intelligence avoided.

Memory Phenomena

The memory phenomena which were investigated can be divided into two areas, encoding and retrieval; each interacted with strategy and memory capacity and long-term memory as well. These two areas as reflected in the memory tasks will be discussed in terms of their different patterns.

Encoding

The phenomenon of encoding was investigated in relation to the issues which had long been examined in relation to deafness, that is, the ability and efficiency in processing temporal information, and the bias towards spatial processing. Das et al. (1979) adopted the terms "successive" and "simultaneous processing". However, these descriptive terms will not be used for the interpretation of the present research, since their associated test batteries were not used in the present research. Lake (1981) preferred to use the term "bias" instead of the term "production inefficiency" coined by Flavell (1971) in her description of the spatial perceptual set of deaf children. In the present research, the terms "mediation /production deficiency", "production inefficiency" of Flavell (1971, 1977) and Flavell and Wellman (1977) provide the reference points in the discussion of the encoding process of the deaf subjects.

First of all, the concepts of presentation and representation had to be distinguished from each other. The presentations of the stimuli in the spatial-position task and the temporal-position task were both executed in sequential order over

time. However, the stimuli were also presented within a spatial area, that is, in the form of a row. Thus, the presentations of the stimuli could be "represented" from either one of the two perspectives. How the stimuli were represented was therefore entirely the encoder's point of view. The research studies of O'Connor and Hermelin (1972) and Hermelin and O'Connor (1973) investigated the preferred representation (or encoding) of the perceptual stimuli in an ambiguous context. Lake's (1981) study provided both an ambiguous context and an unambiguous context to distinguish between bias and efficiency in memory representation. In the present study, the subjects were given the ambiguous context but were also made aware of the ambiguity. They were required to encode both spatial and temporal positions, keep them in retention, wait for the ambiguously-worded question and produce a delayed recall. Therefore, what was investigated was not which was the preferred code or representation; it was solely an investigation of encoding efficiency with rehearsal as well.

Previous studies (e.g., Clark, 1977; Pollard, 1977; Harris & Arnold, 1984) employed both kinds of stimulus presentation, sequential and configurational. In the present study, each presentation was both sequential and configurational. Although the first and the third items were never asked, nor the left and the right, the spatial middle could be the temporal first or third, while the temporal middle could be the spatial left or right. Strategic encoding was necessary for task performance. A possible strategy could be rehearsal of the sequence with the mental representation of

the spatial array, and then isolation of the correct response. Or it could be the repeating of the relevant temporal middle and spatial middle, or spatial middle and temporal middle in cumulative rehearsal.

Strategic performance could be affected either by mediation deficiency, production deficiency and production inefficiency, according to Flavell (1971, 1977) and Flavell and Wellman (1977). Mediation deficiency is the inappropiate use of a strategy in a context requiring another strategy. Production deficiency is the non-use of an available strategy, not because of the lack of capability. Production inefficiency is the inadequate use of a strategy due to less developed skills.

If a deaf subject was extremely spatially biased, he/she would consistently use the spatial code, and also temporal-to-spatial confusion would be predominant. This would be the case of mediation deficiency for temporal processing. Production deficiency would be marked by high spatial position recall and low temporal position recall as well, but errors would be of a random nature. Production inefficiency would be the case where the encoding process itself was inefficient, not just the encoding of temporal information. Both types of recall would be low. Spatial position recall might not differ from temporal position but there would be roughly the same number of temporal-to-spatial confusion errors as spatial-to-temporal errors and a large number of random errors as well.

The results of the whole sample indicated that mediation deficiency for temporal processing was not evident. Although spatial

position recall was higher, the mean temporal position scores were not significantly different from the mean spatial scores, nor were the two types of errors significantly different from each other. The general results showed some indication of inefficiency in encoding as there were significantly more random than spatial-to-temporal errors. However, the picture was not as simple as that. In the contingency analyses with the breakdown into 3 age groups, a different pattern emerged for each group. Another aspect concerning encoding was its relationship with metamemory performance, which suggested that not merely perceptual skills were involved; this will be discussed in another section.

The interesting finding was that both the preadolescent and adolescent groups performed better on the temporal position recall than on the spatial position recall, whereas the late adolescent-young adult group showed a very depressed performance on temporal position recall and also their performance on the spatial position recall was lowest among the three groups although better than their temporal performance. The informal color sequence matching task also produced similar results, with the majority of the sequence users being from the youngest and adolescent groups. Half of the oldest subjects were simultaneous strategy users. Furthermore, the oldest group had the most temporal-to-spatial confusion errors. All this evidence could be taken to suggest that some subjects of the oldest group had a spatial bias, and their temporal processing could be described as showing a mediation

deficiency in addition to the production inefficiency shared by all groups, as two-thirds of them also made random errors.

The adolescent group in general did not show a mediation deficiency of temporal encoding; however, production deficiency for spatial encoding seemed to characterize this group as well as production inefficiency. There were about one-third of this group who made temporal-to-spatial errors and two-thirds who made random errors. Also nearly 62% of this group showed below average performance on the spatial order recall; it seemed that the encoding process was less than efficient although the pattern of bias was reversed, with only approximately 46% performing below average on the temporal version. The cause of inefficiency might be due to other distracting factors in encoding, as this group had the highest number of random errors and 62% of the group had such errors.

The youngest group could be described to be the group showing the most temporal bias instead of spatial bias; only 40% of them showed below average performance on temporal order recall, but 60% showed below average performance on spatial position recall. The percentage of persons in the group making the 3 different types of errors remained constant at 40%. Therefore this group could be described as showing some production inefficiency overall regardless of codes.

In sum, the performance of the deaf subjects was heterogeneous; the pattern discerned was based on what was exhibited by the larger proportion of the group. What the results suggested was that mediation deficiency for temporal position recall was only

associated with the oldest group; the efficiency of temporal order recall increased with age decrease. Yet overall, there was a problem of production inefficiency especially with the two older groups. However, the results and interpretation should be taken with the understanding that there were unequal numbers in the groups. Since the test did not tap just one type of encoding, there was more demand on selective attention, strategic encoding and rehearsal, and it seemed that the oldest group was the most penalized on these aspects. The significant positive correlation of the temporal position test with digit span suggested that capacity and rehearsal were critical elements involved. However, since the number of items used was only three, it did not seem likely that the capacity of the subjects was exceeded as all subjects succeeded in the 3-digit trials of digit span. The majority of subjects in both the oldest group (83.34%) and youngest group (80%) had below average performance on digit span, yet their patterns of performance on the spatial versus temporal position encoding task differed. It seemed that the temporal processing of the youngest group was affected only when increasing units of information were used, whereas the deficiency in temporal processing of the oldest group was more pervasive. What seemed to be more critical was the delay between presentation and questioning, which required more rehearsal of two possible responses and also selective attention to the requirement of the question.

Retrieval

Retrieval performance is differentially affected by task requirements and task conditions. These differences seem to affect the kinds of strategies used. Conversely, to be successful, theindividual needs to be aware of the nature of the task and attune to its strategic requirements. These are the basic principles regarding retrieval as discussed by Flavell (Flavell, 1971; Flavell and Wellman, 1977). Although a substantial number of studies have been done in this area under the metacognitive paradigm with normal children's retrieval strategies, little has been done with deaf children.

What has been seriously neglected is the active retrieval process of the deaf person, the strategy use of deaf individuals in reponse to different stimulus environments and the development of strategic behavior. Research approaches which examine these phenomena need to consider the concepts of production or mediation deficiency and production inefficiency mentioned in the last section, which can be looked upon as indicators of the effectiveness of the individual's learning mode.

Strategy use depends on the individual's discovery of the structure existing among the stimuli or a possible structure that could be constructed based on the current knowledge base that the person has. In the first case, the performance is more stimulus-driven and automatic than in the second case. Using the ideas of Naus & Ornstein (1983), the first case is directly mediated by the knowledge base, whereas the second case is indirectly mediated

by knowledge and is more dependent on strategy mediation. The knowledge base as referred to here is the declarative and procedural knowledge of the stimulus content.

In order to be strategic in retrieval, metamemorial knowledge of strategy-facts and strategy-procedures has to be activated as well. The model proposed by Pressley et al. (1985) suggested that these two types of declarative and procedural knowledge closely monitor the effective use of strategies. If the metamemorial knowledge of an individual is incomplete, retrieval which requires strategy-mediation will be less optimally performed. If the inadequacy lies in the declarative knowledge of the strategies involved, mediation deficiency will result. If the inadequacy is due to the lack of declarative knowledge of unfamiliar task environments, production deficiency will be manifested, whereas if the procedural knowledge of the strategies involved is inadequate, production inefficiency will then be the result.

The memory tasks, namely free-recall and paired-associate learning, were designed with different levels of potential semantic and organizational structure; the prototypic condition in the latter was the most obvious structure. Using the ideas of G. Mandler (1979), the stimuli in the free-recall test had four potential hierarachical structures. The two paired-associate conditions were made up of coordinate (relational) structures. However, the stimuli in both free-recall and paired-associate conditions could be processed as pro-ordinate (serial) structures, depending on the individual's facility with the assumed knowledge base (long-term

semantic memory) and metamemorial knowledge base. Whatever structure was used, it was constrained by memory capacity; however, the use of the appropriate organizational strategy consonant with the inherent stimulus structure would reduce the strain on capacity.

The recall tests could be placed on a continuum of strategy requirement. The prototypic condition of paired-associate learning was a situation with little strategy requirement, as the stimuli were highly familiar associations stored in the long-term memory. As for the free-recall test, it required both familiarity with the semantic relationship inherent in the stimuli, as well as the strategic requirements of the situation and the procedures to effect clustering; strategy use would be under the indirect influence of the knowledge base . The non-prototypic condition in paired-associate learning would require an indirect knowledge base influence for the construction of a coordinate relationship; it would be the use of elaboration strategy. If knowledge was not utilized, then only a primary strategy of recursive rehearsal would be used in both free-recall and the non-prototypic paired-associate condition.

(1) Free-Recall

On the free-recall task, a great variability in the use of clustering was evidenced. Free-recall seemed to be more determined by semantic memory, or the knowledge base, since the highest correlation was with word review. Metamemorial knowledge as assessed in the four subtests seemed to play a secondary role, and the effect of metamemory was reflected negatively, with a weak negative relationship between seriation and study plan. The weak correlation

with opposites-arbitrary suggested that the awareness of different word taxonomies was partly involved; again, this indicated the part played by semantic knowledge. This correlation also suggested that knowledge of the content structure of the task was involved. However, the subtest study-plan was not significantly correlated with clustering strategy. This subtest in fact tested the use of strategies involving categorizable items, and the lack of correlation between the free-recall performance score, the clustering score and study plan was unexpected. Several possible reasons might explain this lack of relationship. Firstly, what was involved in actual task performance might be other monitoring strategies not assessed in the study plan subtest. Secondly, what study plan measured might not be directly relevant to free-recall task performance. Since the final scoring was based on both personal strategies and attributed strategies to a four-year-old child, perspective taking and hypothetical thinking were assessed.

Strategy use was either appropriate or inappropiate. The inappropriate use of seriation instead of clustering would be a case of mediation deficiency. Five subjects, two preadolescents, two adolescents and one late adolescent, had high seriation scores and below average clustering scores. The seriation score was negatively and significantly correlated with word review, while clustering was significantly and positively correlated with word review. Again this indicated that in free-recall, the strategy used was influenced by the level of semantic knowledge. All the youngest subjects had below average clustering scores, some of the adolescents and over half of

the oldest subjects also had low clustering scores. This pointed to the possibility of production inefficiency especially for the youngest group. What the exact cause for this production inefficiency was could not be clearly discerned in the present research.

One possibility was that although four categories could be isolated from the word list, the inter-item associativeness was not equally strong. In fact, only the "fruit" category had the highest frequencies of recall on three items, whereas the "place" category had the lowest total recall frequencies. This reason pertained to the richness and interconnectedness of the knowledge structure of the individual. As the words were reviewed in the beginning and the subjects' knowledge level of these words was established at 80% cut-off point, the fact that predominant influence from semantic knowledge was still observed needed interpretation. Furthermore, during word review, only two subjects did not know one of the sixteen words that were later used in free-recall. Production could be affected by memory capacity because rehearsal over time was required as well. However, this was not likely the overiding factor as digit span only came close to a significant correlation with clustering. A third possibility involves metacognitive factors, that is the lack of efficient executive processes such as monitoring (e.g., Brown, 1978) or superordinate processes (e.g. Belmont, 1978). This third reason was not assessed in the research, although behavioral observation showed that some subjects were not utilizing study time well. The use of seriation strategy by five subjects, which was nearly a

quarter of the sample, also substantiated the metacognitive explanation, in that there was a lack of sensitivity to systematic strategy use. The weak relationship between seriation or clustering and the metamemory aspects assessed in the subtests did not necessarily rule out the metacognitive interpretation.

(2) Paired-Associate Learning

Memory was investigated in another task context, i.e., paired-associate learning. Although the level of frequency and difficulty of the items was similar to the words employed in free-recall, the level of strategy requirement was different.

The retrieval performance on the prototypic condition was marked by ceiling performance; in fact, the stimulus-pairs were so easy that three test items had zero variance. The prototypic condition correlated with only word review among all the measures, at a .051 level of significance. It seemed that the stimulus cue alone was sufficient to evoke the associated response. Although semantic memory still played a part, the assessment with word review was marginally predictive of the retrieval process in this condition, which appeared to have activated automatized responses, bypassing the use of strategy. It could be argued that semantic memory in fact contributed to the high performance on the proto-typic condition, but semantic memory was not adequately indicated by the word review assessment.

Retrieval on the non-prototypic condition, however, showed some constrasting characteristics to the first condition. Apart from significant mean recall difference, with lower performance on the

second condition, this condition appeared to be more strategy-mediated than the prototypic one. The moderately high correlations with both temporal position recall and digit span implied that the retrieval process was similar; possibly cumulative rehearsal over time was used. Interestingly, this condition correlated at a marginal level with free-recall, but not with word review, which meant that semantic memory was not the commonality. The probable commonality would seem to be a shared rehearsal element. Although it had been envisioned that the use of elaboration strategy, either verbal or imaginal, would be appropriate for the retrieval process in the non-prototypic condition, the post-test probes did not indicate that stimulus prompted semantics had been utilized in imaginal construction. The prototypic condition was easy because it was designed with conventional scripts into which the slotting of responses became automatic. However, it was not suggested by the correlations that construction of script-like associations had been attempted, as semantic knowledge was not correlated with the non-prototypic condition. The subjects seemed to have opted for a strategy of a primary nature, that is, rehearsal. It could not be said that all associate pairs were uniform in terms of internal consistency; two pairs seemed to be easier than the rest, resulting in a low reliability coefficient. Perhaps the task was still simple enough that a secondary organizational strategy was not seen as necessary. A better test might be one that involved more words in the association or an arbitrary word list for free-recall with control subjects and experimental subjects trained in elaboration.

Metamemory

Metamemory will be discussed firstly, as measured by the subtests; secondly, in terms of its relationship with memory measures; and thirdly, in terms of characteristics particular to the deaf subjects. Then the concept of episodic and semantic memory distinction in relation to metamemory will be discussed. Lastly the developmental aspect of metamemory in the deaf sample will be considered.

Of the four metamemory subtests, retrieval event had the highest correlation with the composite score followed by study plan and story list. The validity of retrieval event as a metamemory measure has been corroborated in the study of Jayawardhana (1983) with mentally retarded adults and the study of Kurtz et al. (1982). The high internal consistency between retrieval event and story list corroborated the finding of Cavanaugh and Borkowsky (1980) which showed retrieval event and story list to be two of the four most valid indicators of metamemory among the 14 subtests of Kreutzer et al. (1975). The high correlation of study plan with composite metamemory in the present study was probably due to the improved scoring procedure which clearly differentiated the dimensions being measured.

Retrieval event is the best measure because it indicates the functional level of the individual from external mediation to internal mediation as described by the Soviet psychologist, Vygotsky (1978). High correlation was also found between story list and retrieval event, which meant that these two subtests in particular

measure something in common. This commonality seemed to be the ability to reflect upon relationships between events. This was a type of elaborative thinking which is documented in literature (e.g., Rohwer et al., 1977; Greer, 1979) to be late in development. Because reflective thinking was measured, that is why both story list and retrieval event correlated most highly with age. Story list had the highest correlation with age, most probably because the ability to express the relationship is more difficult than giving examples of strategies based on relationships, and better expressive power comes later in development. (The developmental aspect will be discussed more fully in the next section.) Study plan, however measured the repertoire of strategies a person possesses and also the knowledge of another person's ability level and strategy level. Thus, this subtest measured perspective taking in addition to personal skills. Although study plan had a high correlation with the composite score, its intersubtest correlation with retrieval event was lower than that of story list. Intuitively, perspective-taking ability should also correlate with age, but the correlation between study plan and age was not significant. Opposites-arbitrary only measured content knowledge, and therefore its intersubtest correlations with the other subtests were low.

Metamemory-Memory Relationship

Metamemorial knowledge was found to be correlated with long-term semantic memory as assessed in word review in this study. (In this section, discussion is focused on short-term memory, in the

last section metamemory and long-term memory will be dealt with in more details.) Free-recall and the associated clustering strategy were also correlated with word review. A significant positive metamemory-memory relationship was only found with clustering and free-recall among the short-term memory tests using word stimuli. Specifically, the performance on free-recall was related to the metamemory subtest opposites-arbitrary which measured content knowledge, although the correlation was in the low range. Since the paired-associate conditions either promoted automatic response or primary strategy use, metamemory-memory relationship was not reflected with the paired-associate task. The results seemed to suggest that metamemory-memory relationship will not be reflected if the nature of the task is too easy for the person. Thus, sometimes when the hypothesized metamemory-memory relationship does not show up in research, the reason may not be due to the inadequate construct validity of metamemory, instead it is because of the nature of the memory task which does not invoke complex strategy use.

One interesting finding particularly important to the encoding ability of the deaf was a low but significant negative correlation between spatial position recall and retrieval event. The relationship between increase of metamemorial ability and decrease of spatial-coding ability could be best explained as that of relative development in reflective thinking and relative transition from a perceptual bias. A number of research studies have reported that a proportion of deaf subjects use temporal processing when faced with ambiguous sequential/spatial stimuli (e.g., Hermelin & O'Connor,

1973; Lake, 1981). The present study also found that the majority of the preadolescent and adolescent subjects were slightly more proficient in temporal processing; only the late adolescent-young adult group could be described as spatially biased.

It seemed that most subjects were at a transitory stage in which spatial perceptual bias was not extreme and temporal processing could take place under conscious control, which the position encoding task dictated. However, the two kinds of encoding seemed not to have arrived at a stage of balance, in which perfect encoding appropriateness under different perceptual and representational demands was achieved. In other words, production efficiency of the "two codes together" had not been achieved. This situation was then reflected in a lower spatial encoding score accompanied by a higher retrieval event score. Higher performance on retrieval event indicated less dependence on external stimuli and more progress toward internal mediation. It seemed that to be able to overcome spatial perceptual bias, a certain amount of reflection on memory codes and knowledge about memory activity was necessary. At this stage of transitional development of the deaf subjects, the negative correlation appeared to reflect an over-compensation. To be able to overcome spatial bias seemed to be a conceptual matter, not a perceptual matter for the deaf. The relationship between spatial perceptual encoding and self-mediating reflection appeared to confirm the ideas of Kail and Siegel (1977) who regarded the developmental trend in encoding as progressing from being perceptually-dependent to conceptually-related.

However, the concern was whether the direction of development becomes more spatially-biased as age increases. Possibly, the spatial bias of the oldest subjects was only reflective of the result of their experience, whereas the temporal processing skills of the younger subjects were possibly due to a different and enriched environment that promoted reflective thinking. Whether age increase progressively decreases spatial bias and promotes overall encoding efficiency for subjects who exhibited reflective thinking, or whether decrease in spatial bias is dependent on reflective thinking only, has yet to be investigated.

Metamemory and Knowledge

The high correlations between composite metamemory, story list and word review seemed to suggest that the common long-term semantic memory or knowledge base was the source of influence. Both specific semantic knowledge and metamemorial knowledge would be best conceptualized as memory in the broad sense, using Piaget's term (Piaget & Inhelder, 1973), or involuntary memory, using the term of the Soviet psychologists. Brown (1975) suggested that "knowing about knowing", which is metamemory, comes under the development of episodic memory, and so does " knowing how to know", which involves memorial strategies. "Knowing", which is semantic memory, is involuntary memory developed out of interactions with the environment. Contrary to Brown's (1975) suggestion, metamemory as measured in the present research seemed to suggest common roots in long-term semantic memory.

Perhaps the conflict could be resolved by recourse to the more refined concepts of Pressley at al. (1985). In their metamemory model about strategies (MAS), declarative metamemorial knowledge is distinguished from procedural metamemorial knowledge. What was assessed in the present research concerning metamemory using the four subtests was restricted to two areas of declarative metamemorial knowledge, namely learner's strategies and general strategy knowledge. These two areas could be considered as part of long-term semantic memory as well. The nature and the content of the subtests actually investigated the stored information derived from previous learning experiences and social experiences. Probably the distinction between episodic and semantic memory is only theoretically separate, but not empirically separate. Moreover, the concept of semantic memory seems only useful when it embraces the knowledge system as a whole, while the concept of episodic memory is relevant for process description. What is more useful is the distinction between factual metamemorial knowledge and procedural metamemorial knowledge. However, in the present research the latter kind was not measured.

The fact that semantic knowledge played a major role in metamemory performance and strategy use in the present research highlighted the knowledge explanation for development (e.g., Chi & Reese, 1983; Gobbo & Chi, 1986). Researchers such as Glaser (1987) and Siegler and Richards (1982) also concluded that knowledge of specific content domains or expertise is a crucial dimension of high level of competence. Even in the later work of artificial

intelligence, researchers have begun to value the superiority of "knowledge-based strategy" as opposed to "power-based strategy" (Minsky & Papert, 1974). The power-based strategy seeks an increase in computational power, such as information retrieval or search algorithms, whereas the knowledge-based strategy improves ways of expressing and utilizing knowledge. This suggestion fits very well with the correlational pattern between story list and word review, retrieval event and word review, study plan and word review, and clustering and word review for the very reason that "construction" with knowledge was important to performance.

Development

The influence of age was more evident on metamemory rather than on the short-term memory tests. The correlation between metamemory and two metamemory subtests, story list and retrieval event, ranged from moderate to moderately high. The correlation of age with word review was low-moderate. The evidence suggested that metamemory developed as a function of age, whereas the age trend was not so distinct on semantic knowledge, the reason being that the subject sample was selected based on a cut-off point of 80% on word review; therefore the knowledge base of the younger subjects was nearly equivalent to that of the older subjects. As for the other short-term memory tests, the more strategy-independent ones would also be age-independent.

Age differences in metamemory were qualitative rather than just quantitative. The scores on an individual metamemory subtest

were in fact interpretation of qualitative differences, in terms of whether more consistently complex thinking was present. Also, subtle patterns were only discernable with the contingency analyses that were conducted on the subtests study plan and opposites-arbitrary, indicating that interaction between person and task variables influenced the extent of age differences that could be observed.

Study plan was a modified version of the original Kreutzer et al.'s (1975) subtest, in that the age of the young child in the other-attribution question was specified as 4-years-old. The scoring system also differed from the general tabulation used by Kreutzer et al. (1975). Basically, the scoring on the other-attribution question was a reversal of the scoring on the self-attribution question. Thus, a subject would score the highest if he/she used complete categorization and attributed either one of the two types of non-strategic behavior to the 4-year-old. A subject who merely attributed a strategy one level lower than his/her own to the 4-year-old would not be credited as having advanced metamemorial knowledge in terms of understanding of person and strategy variables. The perspective-taking aspect was not given much notice even in the original Kreutzer et al.'s (1975) analysis. The present scoring system, however, regarded perspective-taking as one valid aspect of metamemory. In fact this subtest had the second highest correlation with the total metamemory score. A better performer would be characterized by both self-knowledge and other-knowledge as described in the person variable of Flavell (Flavell & Wellman, 1977). This

would be a stage of decreased egocentrism and decentering in development as suggested by Inhelder and Piaget (1958).

The nearly significant correlation between study plan and age, however, did not lend full confidence in support of a strong developmental trend among the deaf subjects in this aspect of perspective-taking. The contingency table showed that although this ability was evident in most of the late adolescent-young adult subjects, over half of the adolescent subjects and most preadolescent subjects were below average in this ability. In a way, the result reflected a developmental delay in a portion of the deaf adolescent subjects, since perspective taking should have taken place in the formal operational period according to Piaget's theory. This lag could be related to studies of social behavior of deaf children who were described as showing immaturity, egocentricity and impulsivity (e.g., Meadow, 1976; Meadow & Trybus, 1979). Less judgmentally, the deaf adolescents seemed to have less complete social knowledge; this fact was also reported of entering deaf college students (Emerton, 1975, 1976).

On the opposites-arbitrary subtest, a developmental trend was not observed. This age independence was due to the high level of performance of nearly half of the subjects who were below 13-years-old. The ability to differentiate taxonomies was reported to have developed by the end of the elementary school years. Therefore, the lack of an age factor on this particular metamemory subtest, in actual fact confirmed the developmental trend reported of the general population (e.g., Bjorklund et al., 1977; Furth &

Milgram, 1973; Lange, 1973). In this regard, deaf preadolescents developed at a comparable pace as the normal children on knowledge of word classes.

The explanation for the age effect on the other two metamemory subtests was more clearcut, as significant correlations were found. Of the two, story list seemed to be more determined by developmental age, possibly because the critical question was on the ability to give reasons for the utility of an elaboration strategy. To score on this question would require first the recognition of the elaboration strategy used in the story presentation. Younger subjects who failed to express the utility of the story format seemed not to have appreciated the importance of using an organization consonant with the existing knowledge base. The importance of knowledge base has been reported by researchers in expert-novice studies (e.g., Chi, 1978; Lindberg, 1980), cross-cultural studies (e.g., Scribner, 1977), and studies that control knowledge level (e.g., Ceci, 1980). Yet the most crucial factor seemed to be whether the individual is able to make use of the knowledge constructively. The subtest story list presented a simple situation comprehensible to Kreutzer et al.'s (1975) kindergarten subjects, and therefore the inherent knowledge base required should be within the grasp of the present deaf sample. Age differences could only be explained by the lack of understanding of "constructivity" of knowledge. The ability to go beyond what is given and recreate information is a very advanced strategy. According to the literature, elaboration strategy is relatively late in development, and its effective use was

exhibited by a small number of seventh to ninth grade students (Pressley & Levin, 1977) and tenth grade students (Waters, 1982). With regard to the deaf sample tested on the story list subtest, their developmental trend confirmed what was reported in the literature. However, the reservation was that this subtest was relatively simple and the use of elaboration was not requested. Yet there was one-third of the late adolescent-young adult subjects who scored below the mean; thus one might suggest there was a developmental delay reflected.

The trend observed on retrieval event would imply that the older the deaf subject, the less dependence he/she had on external mediation or social mediation. This subtest was actually the most developmentally oriented as the content assessed the functional shift from interpsychological plane to intrapsychological plane which occurs in adolescence (Vygotsky, 1978). Since the majority of the subjects were above 13 years old, it was expected that the oldest subjects should all show above average performance. However, one-third of them still performed below the mean, and over 40% of the subjects chose strategies which are social or external mediations rather than self-mediation in the first trial.

In fact, what should have been expected was a lack of positive age-metamemory correlation since the sample consisted of a majority of adolescents and late-adolescents, and a ceiling performance should have characterized 75% of the subjects. Perhaps, the scoring system did not reflect the generally more detailed examples that the adolescent and late-adolescent subjects gave.

Neither did it give credits to the number of examples the subjects offered. Had this been done, the older subjects would have been shown as performing at uniformly high levels.

Taking the moderately high correlation between the total metamemory score and age, it could be argued that a substantial part of the variance in performance was not predicted by age alone. The consistently higher correlations between the composite metamemory score, three metamemory subtests and word review seemed to implicate that knowledge was the more likely predictor of metamemory.

Summary

The goal of the present research was to provide a descriptive profile of metamemory, short-term memory (encoding, retrieval), strategy and long-term semantic memory, and their interactions with age and task variables in a sample of deaf students. Although internal consistency was achieved with most of the test instruments, the research suffered from several limitations: small sample size, limited test items, test-retest reliability and control for intelligence level.

Both encoding and retrieval were discussed in relation to strategy use, which were considered under the concepts of "mediation deficiency", "production deficiency", and "production inefficiency". Retrieval was also discusssed in terms of knowledge mediation and metamemorial knowledge, while encoding behavior was related to metamemorial knowledge.

The encoding of deaf students in general did not indicate mediation nor production deficiency in temporal position processing. However, some of the oldest deaf students seemed to be characterized by mediation deficiency in temporal processing. The encoding process and its relationship with a metamemory subtest did indicate certain production inefficiency pertaining to encoding both spatial and temporal information simultaneously for all subjects. Also temporal position encoding seemed to be partly governed by working memory capacity.

The analysis of strategy use was incorporated in the analysis of retrieval performance. Strategy use was suggested as differentially affected by the extent of influence from the knowledge base, and adequacy of declarative and procedural metamemorial knowledge. The use of a clustering strategy on free recall was more influenced by semantic knowledge than declarative metamemorial knowledge. High retrieval on free-recall did correlate with the use of clustering strategy. Both the oldest subjects and the youngest subjects were less proficient in clustering. Production deficiency could be caused by the degree of associativeness of the items and the cohesiveness of the knowledge structure of the person. Production inefficiency could be affected by the overloading of memory capacity or the lack of executive strategies.

Ceiling performance was exhibited on the prototypic items of the paired-associate learning task. Responses seemed to be highly automatic, with no dependence on strategy use. Performance on the non-prototypic condition was more dependent on the primary strategy

of rehearsal; the use of a secondary organizational strategy was not evident.

As for metamemory, retrieval event proved to be the most reliable and valid indicator of general metamemory, while opposites-arbitrary the least. Metamemory-memory relationship was not present across all short-term memory tasks. The lack of correlation with paired-associate learning was interpreted as resulting from the low level of difficulty of the memory task. Metamemorial knowledge, however, was associated with the use of clustering and non-use of seriation on the free-recall task. The high correlation between metamemory and word review suggested that the declarative aspects of metamemory were an integral part of the long-term semantic system.

A possible developmental trend was explored. Age was more correlated with metamemory in general than with long-term or short-term memory, although the relationship was still in the moderate to moderately high range. Depending on the different difficulty levels of the metamemory subtests, a developmental trend was not uniform across all subtests. However, the less optimal performance of some of the oldest subjects suggested that there was a developmental lag on metamemorial knowledge when considered in terms of expected functioning level of adolescents.

Concluding Remarks

In conclusion, the present research was not undertaken with an ability-deficit assumption; the interest was more in exploring the

use of strategies in the memory processes in relation to metamemory and knowledge. Although nearly all deaf subjects across the age range exhibited very limited memory capacity, their performance on different memory tasks was not uniformly affected by capacity. Thus the usual comment of deaf people's poor short-term memory based on their memory span could not be accepted, as capacity was not proven to represent the total picture of the memory processes that are involved. Furthermore, development seemed to be relatively independent of the limited capacity in various task situations. The more relevant and urgent questions were the strategy use of adolescent and young adult deaf students, in relation to mediation and/or production deficiency and production inefficiency, since the depressed performance of some of these subjects could not be explained by maturational factors.

The issue of strategy use was more focused on the free-recall task, since the strategy of clustering was adequately quantified. It was particularly with respect to the use of clustering that concerns were raised; even with the presence of factual metamemorial knowledge, efficient usage of strategies was not ensured. What might be lacking in the older and less successful deaf students seemed to be another kind of skills, probably procedural metamemorial knowledge (Pressley et al., 1985) and general executive strategies which involve planning, monitoring and evaluating (Brown, 1978). This was inferred from the observation of the highly successful subjects who showed some self-questioning and monitoring behavior in the retrieval process. It seemed that the more

successful subjects were able to use additional strategies to improve on the basic ones. One subject, for example, apart from using categorization on the items in study plan, also suggested categorization according to corresponding functions associated with different parts of the body in a top-down order.

The present research also uncovered some new understanding with regard to the perennial encoding (representation) problem of the deaf. The ability to encode both spatial and temporal information seemed to be not only a perceptual ability, but a conceptual and strategic ability for the deaf. This ability might not be present in all deaf persons without deliberate learning and reflection. The negative relationship between a metamemory subtest and spatial position recall indicated that a more flexible encoding process is preceded by the development of internal mediation. In other words, more self-direction and introspection are needed. Most of the adolescent and pre-adolescent deaf students showed slightly better performance on temporal position recall in contrast to the oldest group. This might indicate that the younger the deaf person, the more flexible is his/her encoding ability. It was also suspected that the spatial bias of the oldest subjects was due to the lack of executive strategies, since a large number of them had low clustering skill in free-recall as well.

One important finding emanating from the present research was the influence of semantic knowledge, or it could be said knowledge in general. Another important finding was that some of the older deaf students seemed to show a delay in social knowledge. The

difference between more capable and less capable deaf subjects seemed to be in the interrelatedness of their knowledge structure which indirectly mediated strategy use over and above the unstructured material or problem. As Chi and Ceci (1987) pointed out, development is the rearrangement of the former knowledge structures. The individual with a more versatile knowledge structure will be less likely confused by unstructured situations. In contrast, the individual with below average knowledge is only able to function within well defined familiar environments or scripts, and therefore deficiency or inefficiency is manifested when novel situations are encountered.

For the average deaf child, hearing loss often brings about communication problem and experiential deprivation. The theories of Feuerstein (1979, 1980) and Vygotsky (1929, 1978) will help to elucidate the origin of this deprivation. In Feuerstein's (1979, 1980) mediated learning theory, apart from maturational processes, development is through interaction with the environment; this concept is similar to Vygotsky's (1929, 1978) theory. Learning is either through direct exposure or mediated exposure to the environment. In mediated exposure, direct experience is altered through the action of an "experienced, intentioned, and active human being" (Feuerstein & Rand, 1977, p.110). According to Feuerstein (1979) mediated learning is a prerequisite to the development of effective and independent cognitive functioning. Vygotsky (1929, 1978) regarded all higher mental functions as developing through interaction with others and therfore having a mediated structure. Learning is social input and

it precedes development. Development is the internalization of the social input from adults and more capable peers. When internalization of skills takes place, the skills become transformed qualitatively and can be carried out independently. The difference between the level of functioning under the guidance of others (potential level) and the level of functioning independently (actual level) is described as the zone of proximal development by Vygotsky (1978). "What children can do with the assistance of others might be in some sense even more indicative of their mental development than what they can do alone" Vygotsky (1978, p.85).

It seems that the deaf child, particularly the deaf child of hearing parents, is most affected in the area of mediated learning. In general, hearing parents experience a greater degree of trauma than deaf parents when deafness of their children is diagnosed (Schlesinger & Meadow, 1972; Mindel & Vernon, 1971), and therefore their effectiveness as mediating agents is compromised. Even if manual communication is used, the deaf child may not have a consistent linguistic input since the hearing parents most of time do not use sign language, and the teachers may use a form of signing different from what is colloquially used by native signers. This communication idiosyncracy was actually observed in the testing process of the present research. Restricted communication possibilites also mean that a deaf child's world is very much restricted to a number of scripts; thus "memory in the broad sense" is less developed as knowledge cannot be acquired and reappraised through the same continuous involuntary learning process that hearing

individuals share. As a result, knowledge about memory or metamemory in terms of both facts and superordinate mechanisms may also be delayed.

Finally, some directions for future research are suggested. As the present investigation of metamemory did not cover aspects of procedural metamemorial knowledge and the use of executive strategies, such as monitoring, planning, evaluating and predicting, only speculations could be made about the underlying causes of problems. Future research with deaf individuals would obtain valuable information by looking into these areas, since flexibility of thinking is implicated by the possession of such executive processes. Research methods conducive to better understanding would be observational studies. Since the area of metacognition of deaf children has barely been explored, the most basic and direct information is from non-intrusive observation. What needs to be investigated is the nature of the daily mediated experience of the deaf child, that is, the quality of interaction between the deaf child and his/her social environment according to whether metacognitive thinking is encouraged.

More research studies replicating the present research method are not recommended, since it was undertaken only for the purpose of bridging the gap between old memory paradigms used in past memory research of the deaf and recent metacognitive and cognitive paradigms. However, the interpretive focal points such as whether the problem is due to mediation/production deficiency or production inefficiency of strategies, and whether external or internal

mediation is present are strongly recommended. The present research has exposed some crucial issues and it is hoped that from here other researchers and educators will continue.

Due to the small sample size, generalizations from the results of this study cannot be made to the entire population of deaf students. Deafness involves not only a sensory handicap. Other variables, such as etiology, social environment, all interact in a complex way which prevents one from suggesting a simple answer to characterize the cognitive functioning of deaf people. The present research methodology can probably be used as a diagnostic probe complementing diagnostic teaching methods. The suggestion is to build on and adapt to the existing cognitive strategies first. Whenever alternative skills or strategies are deemed functional and necessary for a particular deaf learner, task analysis has to be carried out first so as to construct a sequence of steps progressing from the existing level to the criterion level. Hopefully more research efforts in the direction of considering the learning processes of deaf learners will help in formulating criteria for fruitful educational methods.

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APPENDIX 1
Metamemory Scoring Criteria

Story List

(Q. 1.)	Easier	1
	Harder	0
	Noncommital	0
(Q. 2.)	Mary	1
	Tom	0
	Noncommital	0

(Q. 3.) Reference to relatedness, attention drawing, or better understanding.

1

"I don't know", or irrelevant details, mere repetition of the situation, noting two things without mentioning relatedness.

0

Study Plan

For both questions 1. and 2. the strategies are classified into 6 possible types. For question 1., the score is given according to the level of strategy selected, the highest score of 5 is given to complete categorization. The scoring of question 2. is the reverse of question 1., on the principle that the subject who attributes a lower level strategy, i.e., passivity and random rearrangement to the 4-year-old child will score 5, but when a high level strategy, complete categorization is attributed to the 4-year-old, a score of 1 is given. Nonresponse is assigned a score of 0.

1. Complete Categorization: the subject verbally or physically sorts into three conventional categories of food, body parts and clothing.

(Q. 1.) 5
(Q. 2.) 1

2. Association: (a) some items are grouped like complete categorization and others by functional association or frequent co-occurrence (e.g., a sock goes on your foot); (b) using some other interconnecting strategies, such as story elaborations, linking up the items in event sequence, alphabetization. In both (a) and (b), all the 9 pictures are considered and included by the subject.

(Q. 1.) 4
(Q. 2.) 2

3. Partial Association: the strategies of association are used for some items, but some items (one or more pictures) are left out in the physical or verbal arrangement and description of functions or connections.

(Q. 1.) 3
(Q. 2.) 3

4. Rehearsal: naming the items, thinking about the items repeatedly.

(Q. 1.) 2
(Q. 2.) 4

5. Passivity: looking, labelling, without a clear hint of self-directed rehearsal.

(Q. 1.) 1
(Q. 2.) 5

6. Random Rearrangement: moving the pictures around with no planful or rational way to help learning the pictures.

(Q. 1.) 1
(Q. 2.) 5

7. Nonresponse: no substantive task-relevant response, such as "I don't know".

(Q. 1.) 0
(Q. 2.) 0

Retrieval Event

The same scoring procedure is applied to both questions 1. and 2., according to 5 possible categories of strategies. In the reponse, the subject usually gives a variety of strategies, some of which may be similar. If the strategies are from the same category, give only one score. Some subjects may give a number of passive strategies and also some active strategies, such as "ask mom", "ask the vet", and "he could think back at that time what happened, who gave the dog to him". In this case, score the best strategy amidst the others, i.e., the active think-back strategy.

1. Self-indirect-elaboration: thinking back of something else which can serve as a retrieval cue for the target date, e.g., "how old was the friend at that time", "who were there", "what other things happened at about the same time".

5

2. Self-direct-elaboration: thinking back about the time, e.g., how many Christmases have passed.

4

3. Plausible note: locating a picture, a record, etc., indications from the dog itself, using all external non-human cues.

3

4. Others: asking other people.

2

5. Impossible note: unlikely external resources, e.g., look at the calendar now to find a mark.

1

6. Nonresponse: no attempt to find a way, such as "I don't know", random guessing, missing the point of the problem, such as "Christmans is Dec. 25th".

0

Opposites-Arbitrary

(Q. 1.) Opposite pairs 1
Name + action pairs 0
Non-commital 0

(Q. 2.) The answers are scored according to 3 categories.

1. Alternatives: the explanation alludes to the fact that there is no other alternatives with an opposite pair, e.g., "when you have one word, you can think of the other". Or there is indication that the subject realizes there are more alternatives for the pair made up of a name and an action.

3

2. Stating: the criterion of alternatives is not verbalized, response may be describing kinds of opposities, repeating the opposite pairs given, saying opposites are always easy, or stating that names are confusing without saying why names are confusing.

2

3. Reasons for action + name pairs: reasons supporting that action + name pairs are easy.

1

4. Nonresponse: "I don't know" or irrelevant response.

0

(Q. 3.) a) The 6 (easy) (opposite) pairs.

1

b) If action + name is chosen as easy pairs in question 1., the choice of 6 easy ones will be scored as

0

c) The 5 (harder) pairs (meaning action + name pairs).

0

d) If the subject changes his mind at a later stage that the opposites are easier than name + action, even if the answer for question 3 is the 6 (easy) (opposite) pairs, the score will be

0

APPENDIX 2

Paired-Associate List

(sunset)-evening *

chicken-(supper) **

(farmer)-harvest *

college-(student) *

(bicycle)-picnic **

bottle-(alcohol) **

(cottage)-couple **

coffee-(kettle) **

(pitcher)-handle *

ticket-(police) *

* Prototypic items

** Non-prototypic items

( ) Cue

APPENDIX 3

Free-Recall Lists

List 1.	List 2.	List 3.	List 4.	List 5
doctor	muscle	driver	tongue	tongue
stomach	circus	muscle	circus	soldier
library	orange	circus	cowboy	church
pumpkin	driver	orange	orange	cherry
tongue	finger	library	church	garage
cowboy	soldier	doctor	banana	banana
church	garage	pumpkin	muscle	finger
banana	cherry	stomach	soldier	cowboy
driver	doctor	soldier	stomach	orange
circus	pumpkin	garage	doctor	library
orange	stomach	finger	cherry	stomach
muscle	library	cherry	library	driver
cherry	cowboy	church	pumpkin	pumpkin
garage	banana	tongue	driver	doctor
finger	church	cowboy	finger	circus
soldier	tongue	banana	garage	muscle

Free-Recall Lists (Cont'd.)

List 6	List 7
pumpkin	circus
garage	finger
stomach	orange
soldier	cowboy
finger	banana
doctor	doctor
cherry	stomach
library	library
banana	tongue
driver	church
tongue	soldier
circus	cherry
muscle	driver
orange	muscle
cowboy	pumpkin
church	garage